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## The rise and fall of the fast breeder reactor technology in the UK: between engineering “dreams” and economic “realities”?

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## ABBREVIATIONS

AEA - United Kingdom Atomic Energy Authority

AGR - Advanced gas-cooled reactor

AERE - Atomic Energy Research Establishment

BEPO - British experimental pile '0'

BNFL - British Nuclear Fuels

Candu - Canada deuterium-uranium reactor

CDFR - Commercial Demonstration Fast Reactor

CEGB - Central Electricity Generating Board

CFR - Commercial fast breeder reactor

DFR - Dounreay fast reactor

DMTR - Dounreay materials test reactor

EFR - European fast reactor

ESI - Electricity supply industry

FBR- Fast breeder reactor

GLEEP - Graphite low energy experimental pile

INFCE - International Nuclear Fuel Cycle Evaluation

Magnox - Magnesium non-oxidising reactor

MOX - Mixed oxide fuel

NDA - Nuclear Decommissioning Authority

NGO - Non-governmental organisation

NII - Nuclear Installations Inspectorate

NNC - National Nuclear Corporation

PFR - Prototype fast reactor

PWR - Pressurised water reactor



REC - Regional Electricity Company

RCEP - Royal Commission on Environmental Pollution

SGHWR - Steam generating heavy water reactor

SSEB - South of Scotland Electricity Board

THORP - Thermal oxide reprocessing plant

TNPG - Nuclear Power Group

U235 - Uranium-235

ZEPHYR - Zero-energy test assembly

## **TECHNICAL ABBREVIATIONS**

KWh - Kilowatt hour

MWe - Megawatt electrical

MWt - Megawatt thermal

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## I. INTRODUCTION

Over the past few years, nuclear energy has been experiencing somewhat of a “renaissance”: having for a long time been perceived as a source of environmental and safety risks, nuclear energy is today increasingly seen as a solution to the problems of climate change and energy security. While the Fukushima nuclear accident has again changed the context, with a number of countries imposing moratoria on the further construction of nuclear power, many Western countries nevertheless are continuing to renew their nuclear programmes (e.g. the USA, Finland, France, the UK), or revisiting their earlier policy of phasing out nuclear energy (e.g. Spain and Sweden).

The renewed interest in nuclear energy brings to the spotlight the technical development of the so-called third and fourth generation nuclear reactors. The future of these new technologies is intimately linked to considerations concerning the perceptions and appraisal of risk, given the centrality of such considerations to the social acceptability of the new technologies. The history of nuclear energy demonstrates that the country-specific context significantly shapes the perceptions, appraisal and the management of risks.

In the past, the evolution of nuclear energy has frequently experienced periods of “renaissance” and great expectations, associated with the promise of new, more efficient and less costly technologies such as fusion and fast breeder reactors. While the visions of the exploitation of nuclear fusion are situated in a relatively distant future, the fast breeder technology, by contrast, might become viable at a large scale within a few decades, provided that sufficient institutional support is in place. Yet, as the history of fast breeder reactors both in France and elsewhere has shown, the great expectations have often been followed by periods that have proven difficult – even traumatising – for the nuclear industry. However, we do not postulate determinism: hype-deception cycles are an outcome of a complex interplay of actors situated in their historical and social context.

This report explores the evolution of the fast breeder nuclear reactor programmes in the UK, from the period of great promises and expectations in the 1950s and 1960s towards their progressive abandonment in the 1980s and 1990s. The project, of which this report is an element, aims thereby to draw lessons relevant for the current “nuclear renaissance” and medium-term planning on the future of nuclear power. Given that the fast breeder programmes were closely interlinked with the general evolution of nuclear power in the UK, this report includes a fairly detailed historical description of this more general ‘nuclear context’. This primarily chronological description of the evolution of the UK fast breeder programmes provides a basis for a comparison between the evolution of the British and French fast breeder reactor programmes. A central question in such a comparison concerns the lateness of the abandonment of the fast breeder programme in France, as compared to most other countries developing this technology. The cross-country comparison will explore the relative influence of the contextual and historical conditions within which the nuclear technologies have evolved in France and the UK on the one hand, and the ‘universal’ factors common to the evolution of socio-technical systems in general on the other.

This exploratory research was based on documentary analysis and eleven interviews of experts involved in, or with knowledge of, the UK fast breeder reactor (FBR) programmes. The interviewed persons and their primary affiliations (rationale for their selection as interviewees) were as follows:

**UK AEA**

1. Gregg Butler, University of Manchester
2. Christine Brown

**CEGB**

3. Leslie Mitchell
4. An anonymous former CEGB employee

**Academics**

5. Steve Thomas, University of Greenwich, economics and energy policy
6. Gordon MacKerron, SPRU, economics
7. Andy Stirling, SPRU, science and technology studies
8. William Walker, University of St. Andrews, Professor in International Relations
9. William Nuttall, University of Cambridge, Judge Business School, engineering and technology policy
10. A social scientist wishing to remain anonymous

**Independent consultants/experts**

11. Alex Henney
12. Walt Patterson

An obvious challenge was of ‘temporal’ character: it was not always easy to find individuals that would have information and experience concerning the programme that was terminated almost two decades ago.

Section 2 of the report traces the evolution of the UK civil nuclear programme since its origins in the 1940s. The report then explains the early development and the challenges in the construction and operation of the experimental and prototype fast breeder reactors in Dounreay. The chronological description ends by a presentation of the plans to construct a commercial fast breeder reactor – plans eventually abandoned in 1994. The report then concludes by exploring a number of different explanations suggested by the interviewees and present in the documents concerning the reasons for the ups and downs in the evolution of the UK fast breeder programme.

The historical description of the history of the UK nuclear and fast breeder history is largely based on works by two authors. The period from 1940 to the mid-50s relies mainly on Margaret Gowing’s works, whereas information for the subsequent years stems primarily from Walt Patterson’s books and publications. Gowing, a historian, was commissioned by the United Kingdom Atomic Energy Authority to write a history of the UK nuclear power sector from its start up to the early 1950s, in “Britain and Atomic Energy 1939-1945” and a two-volume series “Independence and deterrence: Britain and atomic energy, 1945-1952”. Patterson, in turn, is an independent energy analyst, and a former NGO activist (founding member of the

Friends of the Earth UK), whose books (1984; 1985) and a more recent summary of FBR development in the UK (Patterson 2010) provide a narrative of the nuclear power programme, drawing facts from sources such as official records, scientific journals, and the media. Numerous articles critical towards the UK nuclear policy and fast breeder programme were also used as basis for the report. Patterson was also one of our interviewees.

On the whole fast breeder reactors did not seem to have occupied a central position in the UK debate on nuclear power, let alone the debate on energy policy in general. Instead, key topics of public and political debate concerned the choice between coal and nuclear, the choice of the preferred thermal reactor technology especially in the 1970s, and the desirability of reprocessing of nuclear waste. The period of most lively discussion on the FBRs was certainly in the 1970s and early 1980s, not least because of the numerous committee reports and inquiry processes, which helped bring to the public arena notable cost estimates concerning of the construction of FBRs. In the relatively scarce academic literature on the topic, economic analysis seemed to dominate, with the journal “Energy Policy” as a major outlet and most of the authors rather critical towards the fast breeder policy in particular and UK nuclear energy policy in general (e.g. Rush et al. 1977, Collingridge 1984, Henney 1987; 1989; 1994, Sweet 1982; 1990, Holmes 1987). More political discussions were reported in professional and specialised press such as the “Bulletin of Atomic Scientists” and “New Scientist”, or in general science journals such as “Nature and Science”. Later analysis, following the practical termination of the UK FBR programme, has touched upon the issue from a broader perspective of social and political sciences (e.g. Parker and Surrey 1995; Walker 1999; 2000) and energy forecasting (Utgikar and Scott 2006). Finally, a substantial body of literature consists of articles written by FBR advocates, many of whom were staff employed by the AEA (e.g. Cutts 1977, Hirsch and Farmer 1986, and Judd and Ainsworth 1998).

## II. THE INCEPTION OF THE NUCLEAR POWER PROGRAMME (FROM 1940)

**Figure 1: General UK Nuclear Programme Timeline**

1945	Atomic Energy Research Establishment (AERE) established under the Ministry of Supply. Uranium metal processing plant in Springfield built (1945)
1946	
1947	AERE 's first 3 kWt nuclear reactor Graphite Low Energy Experimental Pile (GLEEP) began operation Began construction for two Windscale gas-cooled piles (1947)
1948	First large 6 kWt nuclear reactor British Experimental Pile 'O' (BEPO) went critical (1948)
1949	
1950	Windscale pile 1 goes critical. Capenhurst (NDA)- low-separation gaseous diffusion plant (1950)
1951	Windscale pile 2 goes critical. Capenhurst (NDA) low-separation gaseous diffusion plant (1951)
1952	Planned shutdown of pile 1. 204 military metal reprocessing plant and finishing plant start up at Windscale (1952)
1953	UK government announced the beginning of the civil nuclear power program. Capenhurst (Urenco) high separation gaseous diffusion plant began operation (1953)
1954	The UK Atomic Energy Authority (UKAEA) established to oversee the nuclear energy program and the Experimental FBR was constructed (1954)
1955	White paper "A Programme of Nuclear Power" announced 1 <sup>st</sup> only commercial program to build 1400 and 1800 MWe of Magnox reactors by 1965 and invest in future of FBR (1955)
1956	1 <sup>st</sup> commercial nuclear station (Magnox reactor) (1956)
1957	White paper on "Capital investment in coal, gas, and electricity industries" proposed to increase nuclear program between 5000-6000 MWe. Fire at Windscale- the most serious nuclear accident in the UK (1957)
1958	The Central Electricity Generating Board (CEGB) was established by the 1957 Electricity Act took over electricity generation responsibilities (1958)
1964	White paper on "The Second Nuclear Power Programme" prompted next nuclear phase with 5000MWe capacity expected between 1970-1975. B205 Chemical separation plant start up at Windscale (1964)
1965	The advanced gas-cooled reactor (AGR) adopted as UK standard – exclusive to the UK (1965)
1966	
1967	
1968	Design and finance problems emerge with AGR during construction phase (1968-onwards)
1975	Steam Generating Heavy Water Reactor (SGHWR) chosen as the new nuclear reactor design with plans to build two plants with a total of 660MWe (1975)
1976	First of 14 AGR units start up (1976-89)
1977	National Nuclear Corporation recommends new AGR ad PWR instead of SGHWR (1977)
1978	Secretary State of Energy announces the abandonment the SGHWR programme and more AGR built along with one pressurized water reactor (PWR) unit (1978)
1979	Margaret Thatcher government takes over and favours PWR designs (1979)
1980	Thatcher government authorised the commission of two more AGR reactors despite favouring PWR designs (1980)
1981	
1982	Capenhurst (NDA) low-separation gaseous diffusion plant is decommissioned (1982)
1983	One PWR was commissioned after two year public enquiry (1983)
1986	Chernobyl accident prompted public outcry on nuclear power generation (1986)
1987	The 1188 MWe PWR was approved and expected to start up in 1994 (1987)
1988	Additional PWRs were planned (late 1980's)
1989	
1990	Government authorised PWR plans (1990)
1994	Government carried out a "Review of the Future Prospects for Nuclear Power in the UK" (1994)
1995	Following the 1994 review, the government concluded that nuclear power did not have sufficient public support. Nuclear Electric (the nuclear division of the National Power utilities) also concluded nuclear plants were not financially feasible and abandoned plans for nuclear power (1994)

Sources: Patterson (1982; 2010), Gowing & Arnold (1979), World Nuclear Association (2011), NDA (2011).

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## 2.1 Military ambitions

The development of civil nuclear power in the UK was intimately linked with the country's ambitions to develop an atomic bomb in the early 1940s. At the early stages of the programme, the harnessing of “the atom” for energy production was generally seen as an example of the use of nuclear technology for peaceful purposes – in the post-war atmosphere a powerful image of new technology converted into socially useful purposes. The link between military and civilian uses of nuclear energy was also an essential determinant for the subsequent evolution of the fast breeder programme.

### 2.1.1 The early pioneers (early 1940s)

Nuclear fission research was initially suggested in the memorandum ‘on the properties of a radioactive “superbomb”’, prepared by two British physicists from the University of Birmingham, Otto Frisch and Rudolf Peierls. The report proposed that uranium 235 (U235) could be separated through an industrial process and used to create an atomic bomb. This so-called Frisch-Peierls memorandum was forwarded to the Scientific Survey of Air Defence and of Air Warfare, which established the so-called Maud Committee, thereby marking the beginning of Britain's atomic research. The Maud Committee, formed to investigate the possibilities of creating an atomic bomb, collaborated with the French scientists von Halban and Kowarski in Cambridge on ‘slow chain reactions’ research, and discovered plutonium, which could be used for developing nuclear weapons and energy (Gowing & Arnold 1979, 14).

The Maud Committee published a report in 1941 reiterating the feasibility of developing the atomic bomb by making U235 through the enrichment process and/or plutonium with nuclear boilers. The report convinced the Americans to restructure their previous uranium programme and proposed to establish a joint British-American project, but the British were less keen to move their project to the US. Thus the Americans carried on independently establishing the Manhattan Project in June 1942, which due to its massive scale was run by the army. In August 1942 the US succeeded in separating the first pure form of plutonium based on the knowledge from the Maud Report. The American efforts had quickly outpaced the British, who came to the realisation that in order to progress with their own atomic research, they would have to collaborate with the US. However, the Americans were less than enthusiastic to join forces and sought instead to secure their own source of uranium by stockpiling the entire uranium output from the Eldorado mines in Canada. Eventually Churchill and Roosevelt signed the Quebec Agreement in 1943 creating a Combined Policy Committee that was to allocate uranium supplies according to each nation's requirement. The Quebec Agreement stipulated that atomic weapons information could not be disseminated or used against third parties unless agreed by both countries. A year later, in 1944, a draft agreement was presented to the Combined Policy Committee proposing that Americans, British, and Canadians collaborate in order to secure uranium supplies during the war. As a result, the “Combined Development Trust” was established as a collaboration between the US, the UK, and Canada (Gowing 1964).



In the early 40s, Britain sent as many scientists as possible involved in U235 and fast neutron bomb research to join the research project in the United States in order to quickly produce an atomic bomb. However, suspicious about Britain's motives, Americans denied British scientists access to plutonium production sites and some sections of the project. Moreover, the Halban and Kowarski's team working on slow chain reaction was moved to Canada to develop a nuclear boiler using heavy water as a moderator. Canada's relative proximity to the US would better facilitate the flow of ideas and resources. Thus in a brief time the core team involved in Britain's early atomic research work was dispersed throughout North America (Gowing & Arnold 1979; Gowing 1964, 71, 135, 269; Edwards 1996).

### 2.1.2 The Atomic Project (mid-1940s)

Britain, concerned with maintaining a good relationship with the US, was hesitant to divert its scientists away from the joint research project before reaching its military objectives. However, not all aspects of the research were directed towards war efforts. In particular, some streams of Britain's research in the US on electromagnetic separation were geared towards non-military applications. Although the primary objectives were of purely military nature, Britain wished to develop its own nuclear plants after the war and establish a nuclear energy project for both civil and military purposes. This would require a continuation of the British-American collaboration even after the war.<sup>1</sup>

Meanwhile, Britain did not wish to passively wait until the end of the war before establishing a nuclear power production facility. Churchill announced to the House of Commons in November 1945 that Britain would develop its own atomic bomb. But at that point, no ministerial committee existed to oversee nuclear-related issues. A semi-formal group of Cabinet Ministers known as 'Gen 75' gathered on an ad hoc basis to address atomic energy issues including domestic policy development, international atomic control, and British-American cooperation. In October 1945 a formal research institution, the Atomic Energy Research Establishment (AERE) was established with members originating from the British-American research team. AERE was overseen by the Ministry of Supply, an existing department responsible for coordinating military supplies and had industry links in the chemical and engineering sector.

In November 1946, the Ministry of Supply's authority over Britain's civil and military atomic project was formally legalised in the Atomic Energy Act. Fast reactors had a key long-term role in this programme (Judd and Ainsworth 1998, 609). Several months later, in December, the Ministers granted approval for the development of experimental graphite reactors or 'piles'<sup>2</sup> for plutonium production. The research facility was built in AERE's establishment in Harwell, Oxfordshire and lead by Professor John Cockcroft. A zero-energy test assembly, 'ZEPHYR', was built at Harwell and used for basic fast reactor neutron physics studies (Judd and Ainsworth 1998, 609). The production unit, with both military and non-military objectives, was located in Risley, Lancashire, and was headed by Christopher Hinton (Gowing 1964;

<sup>1</sup> An example of such collaboration was the Hyde Park Aide-Mémoire, signed in September 1944 between the US and Britain, to develop tube alloys for military and non-military applications.

<sup>2</sup> A 'pile' is the early nuclear reactor with a core built with layers of graphite and intermittent layers of uranium oxide (Atomic Archive 2011).

Gowing 1974b). From the onset, Harwell was given special privileges due to the perceived significance of the expected research outcomes. Cockcroft himself was also offered a privileged position and would only have to report to the Minister and his Permanent Secretary within the Ministry of Supply. Harwell's research and development laboratory, run mainly by physicists, was thus secured to freely choose its research topics, guided by its own interests, although the laboratory's main purpose was to provide information for the experimental piles. In order to drive scientific discoveries, the establishment was to draw from the top scientists, institutions and universities, requiring flexible administrative process and readily accessible funds. As a result, there was little control over expenditures and the manner in which funds were distributed.

**Figure 2. Location of AEA sites at the end of 1990s.**

(At this time the AEA's activity had already been strongly phased down, including the closure of the Springfield site in Lancashire)



Source: HSE 1998, 6

The research establishment at Harwell would essentially function as an academic research laboratory, publishing work without compromising military security. The production branch of Britain's atomic project in Risley was run by an acclaimed engineer, Christopher Hinton. He took charge of the design, construction and operation of the large-scale production plants, despite Britain's initial reservations to avoid large fissile production facilities.



The relationship between Risley and Harwell was precarious from the start. The research establishment focused on programmes based on ‘curiosity-oriented research’, where there were no specified areas identified for practical future uses and there were no expectations set to produce results that would lead to benefits (Gowing 1974a, 207). On the other hand, the production organisation, dominated by engineers, was more interested in ‘action research’, which focused on working towards specific applications that would lead to an intended benefit and not only on furthering knowledge (Gowing 1974b, 237). However, at least initially, the industrially oriented organisation also had to depend on Harwell’s research. Harwell’s scientists were also at times reluctant to accept general programmes (orders, commands and timetables) by Risley’s engineers, who needed to meet plant deadlines. Furthermore, when projects succeeded, Harwell publicly took credit for the achievements since Risley’s involvement had military implications and could compromise national security. Eventually, Risley set up its own applied research and development capabilities in 1949 and Harwell its own industrial engineering branch (Gowing 1974a).

The first pile constructed at Harwell was the 3kW Graphite Low Energy Experimental Pile (GLEEP), which went critical<sup>3</sup> in August 1947. The pile was based on work completed by the British-Canadian research team and was built as an experimental pile for testing instruments and designs, as well as making radioactive isotopes. Following the construction of GLEEP, the British Experimental Pile ‘0’ (BEPO), an air-cooled, graphite moderator fuelled by natural uranium, was built in June 1946 with 6000kW of operating power. Only two years later, in July 1948, BEPO went critical with relatively little difficulties. This success gave British engineers and scientists the confidence to scale-up BEPO and to build ‘super-Harwell’ piles, thereby paving the way for Britain’s first commercial reactor. Crucially, Britain’s brief experience with the experimental piles at Harwell would set the design for fast breeder reactors over the next two decades (Gowing 1964; Gowing 1974b).

While work was underway on the experimental piles at Harwell, the Ministers formally approved the production of atomic bombs in January 1947. Britain sensed an urgency to develop atomic weapons in order to prevent the Americans from monopolising atomic weapons production, particularly with the deterioration of the British-American cooperation, aggravated in 1946 by the McMahon Bill passed in the United States. The McMahon bill placed restrictions on sharing scientific and technical information on nuclear technology with other countries, including US allies. Britain also feared Russia’s progress in developing an atomic bomb.<sup>4</sup> Mounting pressure to catch up with the Americans and Russians became an issue of national pride and a need to retain a balance of power. The British politicians reasoned that if

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<sup>3</sup> In nuclear fission, criticality occurs when the critical mass, i.e. the smallest amount of fissile material needed for a sustained nuclear chain reaction, is achieved. The number of neutrons produced from the fission process as well as the power generated in the system remains constant.

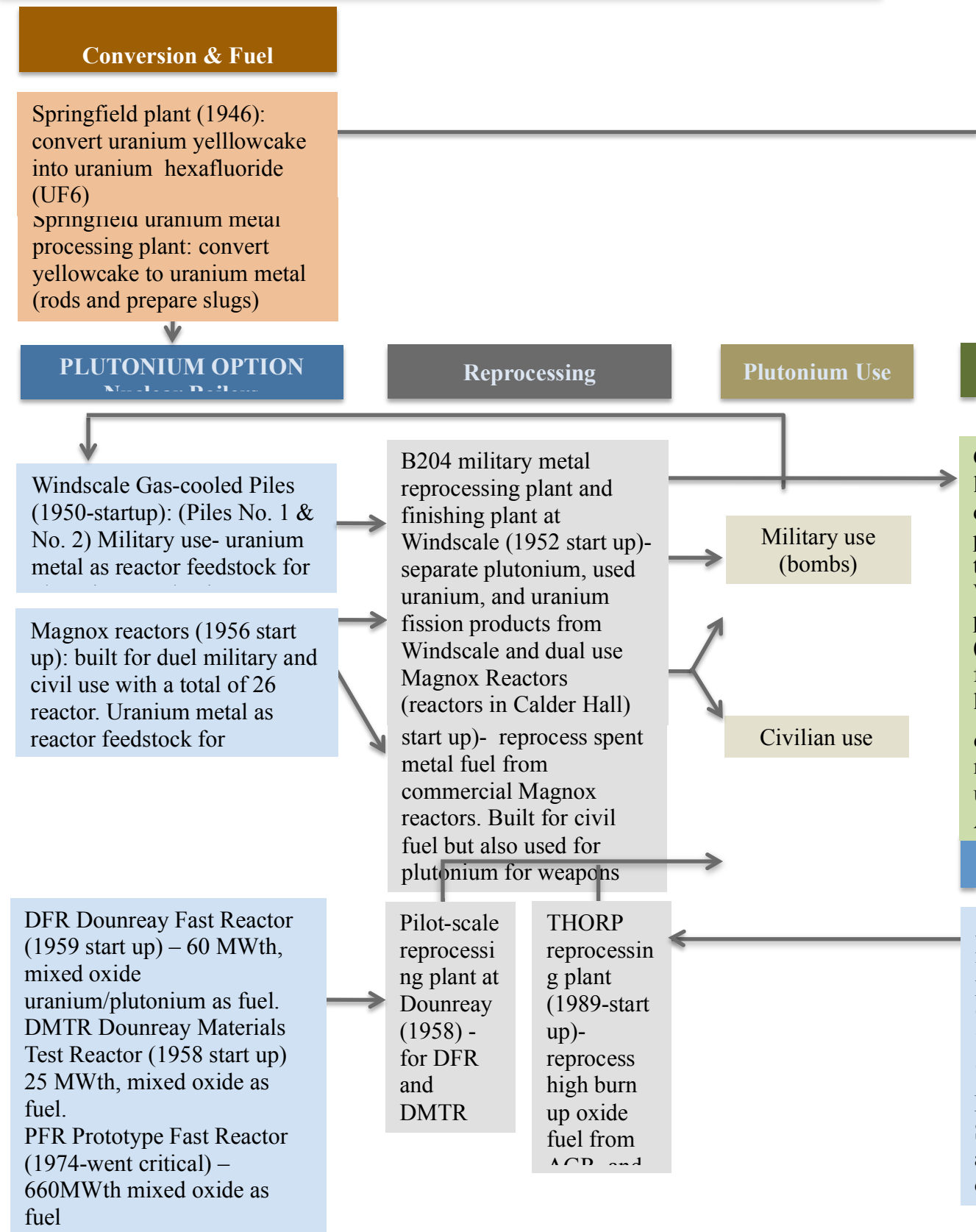
<sup>4</sup> According to the report published by the Joint Technical Warfare Committee of the Chiefs of Staff in 1946, it would have taken several hundred atomic bombs to devastate Russia but only 30 to 103 atomic bombs from Russia to bring down Britain – although the report did not explicitly define Russia as an enemy.

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the UK succeeded in producing the atomic bomb, the Americans would view them more favourably and consider them as their special ally (Gowing 1974a, 15).

The initial atomic plan was to focus on plutonium production for military needs. Hence, in March 1946 the decision was made to construct the Springfield uranium metal processing plant in Preston under Hinton's leadership. The uranium processing plant would convert uranium ore to canned uranium metal slugs, feed material for the Windscale piles and Magnox reactors, which would in turn produce plutonium (see Figure 3 for UK's plutonium and uranium-235 production route).

**Figure 3: Production of fissionable materials: the plutonium route and the uranium-235 route**



Sources: Patterson (1984; 1985; 2010); Gowing (1974); Hinton (1953); Westinghouse (2006); NDA (2011). Henney 1989; World Nuclear Association, 2010

With the decision to make the atomic bomb, Britain also contemplated on building a gaseous diffusion plant in the mid-1940s to produce enriched uranium - though the plant would be constructed only in the 1950s. The choice to build a U235 plant was based on the assumption that uranium supplies would be limited, on economic calculations, and on the need to secure a long-term future for nuclear energy production. Expected shortages of uranium supplies meant that recycling was seen as an attractive option either by mixing the used uranium from the 'irradiated fuel elements' and adding in enriched uranium in a gas diffusion plant or through 'seeding', that is, by adding plutonium with the fuel elements. Adding U235 for re-enrichment, however, would produce almost three times more military grade plutonium compared to seeding with plutonium. The uranium plant would also provide an economic means of supplying raw materials for the atomic bomb. Crucially, research and development for the use of U235 was expected to lead into further research for nuclear power development with the fast reactor which would produce more fissile material than it would consume. The decision to start uranium enrichment was therefore based on the logic that was to underpin the subsequent development of fast breeder reactors, i.e. the belief that "any large-scale exploitation of atomic energy" should "ultimately depend on this breeding" (Gowing 1974a). Although the uranium processing plant in Springfield was built with military needs in mind, scientists and engineers had already thought of using U235 for fast breeder reactors to produce energy (Gowing 1974a; Henney 1989; World Nuclear Association 2011).

Therefore, developing an atomic bomb independently from the United States was not only an issue of national pride and self-sufficiency, but also an investment in a future technology that would strengthen Britain's power industry. This was particularly important, since sourcing labour for mining coal was becoming increasingly difficult. Consequently the Directive on Priority for Atomic Energy was set in 1947, emphasising the importance of nuclear energy development in the UK.

### **2.1.3 Windscale reactors (from late 1940s to 1950s)**

As work proceeded at Springfield, plans went ahead for a large-scale production programme. Initially, Britain considered building a water-cooled pile for plutonium production, similar to the design used in the Manhattan project. The water-cooled piles presented certain technical difficulties and safety concerns due to corrosion. The pile also required large quantities of pure water. The only appropriate location for a large-scale water-cooled pile was identified near the Morar River in the west of Scotland, which nevertheless lacked transportation routes and facilities. Hinton proposed to build one air-cooled pile and another pressurised gas-cooled pile. The first pile would produce plutonium and draw on the experience from the experimental gas-cooled piles while the second, modified from the original gas-cooled pile, would operate at high temperatures enabling the generation of power and the production of plutonium. The pressurised gas-cooled pile would require more time to construct, but Hinton argued that the design was superior to the water-cooled pile. However, the ministers were hesitant to build the pressurised gas-cooled pile, which would slow down construction and plutonium production but would speed up the overall development of atomic energy technology. Despite the gas-cooled piles' higher capital and operating cost, relative to other reactors, Britain pushed forward with a

large-scale gas-cooled piles programme in May 1947, abandoning the water-cooled and pressurised cooled pile design.

The gas-cooled piles and its auxiliary plants were built at Windscale and the uranium metal processing plant in Springfield built in 1946 would provide the fuel for the piles. The first uranium casts were produced at Springfield uranium metal processing plant in 1948. Approval to build a third Windscale pile was granted in February 1949 along with the Capenhurst low-separation gaseous diffusion plant in 1950, but work on this third pile was put on hold at the end of 1949.

Windscale pile No. 1 went critical in 1950 and pile No. 2 in 1951. However, overheating issues at pile No. 1 lead to the decision to shut down the plant in 1952. Nevertheless, progress continued with the programme and in 1952, the B204 military reprocessing plant and finishing plant was commissioned at Windscale followed by the B205 chemical separation plant in Windscale that started up in 1964. In October 1952 Britain tested its first atomic bomb in Monte Bello, Australia, thereby demonstrating to the world that it possessed the military and industrial capabilities to pursue its own atomic programme. Monte Bello was seen as an important accomplishment and a significant step towards establishing the foundation for nuclear energy generation over the next decades (Gowing 1974a; World Nuclear Association 2011).

## **2.2 The civil nuclear power programme**

After the war, the civil use of nuclear power gradually gained importance along with the military objectives that had until then dominated research and development in the area.

### **2.2.1 Motivations for the nuclear programme and the creation of the AEA (1950s)**

Britain's involvement in the production of the atomic bomb helped establish the necessary institutions, research organisations, and technological infrastructure needed to develop a civil nuclear power programme. However, a number of technical challenges, institutional conflicts, and external political and economic events significantly influenced the technological pathway of nuclear reactors. Although Harwell and Risley encountered numerous issues related to technology, costs, efficiency and timeliness, the nuclear programme was perceived to progress well early on. There was limited transparency despite the fact that Harwell, in theory, was to function like an academic institution. In practice, the research and production laboratories were forbidden to openly discuss their problems and challenges. As a consequence, “the task seemed deceptively smooth and easy, so much so that disillusionment was to lie ahead” (Gowing 1974b).

Nevertheless, British scientists and engineers won the government's support for the development of the atomic bomb and also saw the potential in producing energy from plutonium production. Ministers, most notably Lord Cherwell, one of the first ministers knowledgeable on science and technological implications associated with

nuclear power, recognised that just as the atomic bomb had transformed warfare, there was potential for nuclear power to revolutionise energy production for industrial needs. Thanks to the political backing, nuclear research and development received significant funding and after the war, the military motivations slowly gave way to large-scale nuclear power production as the main focus of the country's nuclear programme.

Early in the 1950s Lord Cherwell was advocating the establishment of a new special organisation that would be 'more flexible than the normal civil service system' to replace the Ministry of Supply's responsibility over nuclear energy. In April 1953, Churchill announced that a new organisation would be established. He therefore convened an advisory committee that subsequently produced an influential report "The Future Organisation of the United Kingdom Atomic Energy Project". Following the report's recommendations, the Atomic Energy Act was passed in 1954, leading to the establishment of the United Kingdom Atomic Energy Authority (AEA). The AEA took responsibility for the development of nuclear reactors for the new civil energy programme as well as the military defence programme (Henney 1989; World Nuclear Association 2011). In 1954 the AEA had nearly 20,000 employees – but by 1961 the number of staff had [more than](#) doubled to 41 000.<sup>5</sup>

### 2.2.2 British reactor technologies (1950s to 1980s)

The launching of a civil nuclear energy programme was officially announced in 1953. The Windscale piles served as a transient reactor that would shift the military atomic programme to a primarily civil one. The new reactor was to be built on the existing Windscale design, with three main alterations:

- pressurised cooling gas was used in order to increase the electricity output and temperature, and to improve thermal efficiency to drive the steam turbine;
- gas (carbon dioxide) instead of air was used as a coolant due to its good heat-transfer capabilities and minimal neutron absorption; and
- magnesium was used as the cladding.

The new Magnox (Magnesium non-oxidising) reactor was the first dual purpose commercial reactor built in the UK. The first order commissioned was the 70MW twin whose construction began at Calder Hall, Windscale, in August 1953. Only three years later, in 1956, Queen Elizabeth opened the world's first commercial reactor. The push for Magnox reactors was supported by the White Paper 'A Programme of Nuclear Power' published in February 1955, which declared the first wholly commercial nuclear energy programme. The paper identified immediate, mid-term, and long-term reactor designs. First, the gas-cooled reactor programme would be developed under the responsibility of the Central Electricity Authority, using the Magnox design to build a capacity of 1400-1800 MWe by 1965. The Magnox reactors would produce plutonium and heat that could be used for energy (Patterson 1985; Ham and Hall 2006).

The next planned reactor design would be a liquid-cooled design, capable of reaching higher temperatures. These reactors were expected to be initially more costly to build

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<sup>5</sup> <http://www.caithness.org/fpb/dounreay/history/>



but would eventually become more economical. The fuel for the liquid-cooled design would derive from enriched uranium and plutonium from the Magnox reactors. The third reactor programme would be based on long-term research and development towards fast breeder reactors using fuel from the first Magnox reactor programme (Hirschfelder 1955). The Suez crisis in 1956 and mounting worries over the availability of coal and oil further drove the Magnox programme. Another White Paper released in April 1957 proposed to expand the nuclear power programme to around 5000-6000 MWe. The electricity would be produced by 19 Magnox stations, expected to be built by 1965. This was anticipated to make up around 25% of UK's generating capacity, at an expected cost of 750 million GBP (Ham and Hall 2006).

The Central Electricity Authority was transformed in September 1957 into the Central Electricity Generating Board (CEGB) and Hinton was appointed to lead the utility – a position he came to hold until 1964 (Cisler 1991). The ambitions of the Magnox programme were scaled down, for a variety of reasons. The reactor was costly, had low thermal efficiency (22-28%), required significant amount of graphite, and also needed reprocessing, because of corrosion in the magnesium alloy cladding when the spent fuel was stored in water.<sup>6</sup> Eventually a total of twenty-six Magnox stations were built and started up between 1962 and 1971 for power generation (around 4200 MWe) and plutonium production. Furthermore, each reactor was built as a standalone prototype by private consortia,<sup>7</sup> which limited the ability to learn and correct mistakes. Consortia were needed in the UK nuclear industry as there were no existing segments of the industry that possessed all the capabilities needed to build new nuclear stations (e.g. electrical and civil engineering, boiler production, reactor physics). Also, the consortia were to compete for tenders to build nuclear plants in the new nuclear programme (Henney 1989; Ham & Hall 2006; World Nuclear Association 2011; Patterson 1985).

Although the Magnox was initially perceived as a promising technology, the reactor later proved to be more costly than anticipated. According to CEGB figures, the Magnox construction costs often exceeded budgeted costs (see Table 1). Furthermore, according to Patterson (1985, 10), electricity generation prices for Berkeley and Bradwell increased from the original tender price of less than £150/KW to £167/KW even before the plants began to operate in 1962.

A further problem for the UK nuclear programme appeared in October 1957 when a fire broke at Windscale, producing the most serious nuclear accident in the UK. The fire “brought the euphoria of the first age of nuclear energy to an abrupt end”, as both Windscale Piles were shut down following the accident, never to be re-started.<sup>8</sup> The fire permanently tarnished the reputation of the Windscale complex, and eventually

<sup>6</sup> The magnesium alloy, used in cladding unenriched uranium metal fuel with a non-oxidising covering to contain fission products, was easily corroded in water, and therefore prevented long-term storage of spent fuel in water.

<sup>7</sup> “Four consortia, each led by one of the country's major manufacturers of heavy electrical plant – Associated Electrical Industries (AEI), the General Electric Company (GEC), English Electric and C. A. Parsons – had been set up by 1955; another was added in 1956. The Authority provided design information and held courses to train staff from the consortia in the subtleties of nuclear engineering.” (Patterson 1985, 5)

<sup>8</sup> Munn, Andy: UKAEA – The first fifty years. <http://www.caithness.org/fpb/dounreay/history/>

prompted in 1981 the decision by the British Nuclear Fuels (BNFL) to try and wipe away the bad memories by changing the plant's name to Sellafield (Walker 2007).<sup>9</sup>

**Table 1: Costs of selected Magnox reactors<sup>10</sup>**

Reactor	Budgeted cost (£ millions)	Actual cost (£ millions)	Cost overrun (%)
Berkeley	144	185	28%
Bradwell	143	175	22%
Hinkley Point A	120	154	28%
Trawsfynydd	123	158	28%
Dungeness A	119	119	0%
Sizewell A	101	106	5%
Oldbury	108	114	6%
Wylfa	118	124	5%

Sources: CEGB 1967 & 1977 cited in Henney, 1989

The Second Nuclear Power Programme announced in April 1964 aimed to generate 5000 MWe of nuclear electricity between 1970 and 1975 and assigned the CEGB the responsibility to choose a new reactor design. The reactor choice was between the AEA's advanced gas-cooled reactor based on the prototype Windscale Advanced Gas-cooled Reactor and the American-designed water-cooled reactors, which was favoured by the CEGB. The CEGB and the AEA disagreed over the reactor choice but eventually the AGR was chosen as the standard UK reactor in May 1965. According to Winskel (2002, 443), “the AGR was essentially an upgraded Magnox design, using enriched uranium fuel and higher operating temperatures.”<sup>11</sup> The AGRs were also built with graphite and used carbon dioxide as coolant but unlike the Magnox reactors, which used uranium metal fuel, the AGRs used enriched oxide fuel in a ceramic state, increasing thermal efficiency to around 40%. But since competing industry consortia were building the different AGRs, the process was hampered by the same lack of standardisation that had undermined the success of the Magnox programme. The construction of the AGRs also ran behind schedule and was burdened with problems of financing. In total, seven stations with twin reactors were built and brought on-line between 1976 and 1989.

The 1970s were a period of confusion and upheaval in the UK nuclear policy, with the choice of the thermal reactor design at the forefront of discussions. To add to the complexity of choices between the Magnox, AGR and PWR, in the 1970s the AEA proposed a new reactor type, the Steam Generating Heavy Water Reactor (SGHWR). After long and complicated processes of decision-making, the SGHWR was

<sup>9</sup> In fact, the Sellafield site in Cumbria had been renamed Windscale in 1946, when it was designated as the new atomic energy site. In 1981, the BNFL portion of the Windscale site, covering the production activities, was renamed Sellafield, while the UKAEA part of the site [the Windscale Piles and the prototype Windscale Advanced Gas-cooled Reactor (WAGR)] retained the Windscale name. [http://www.world-nuclear.org/info/inf84a\\_nuclear\\_development\\_UK](http://www.world-nuclear.org/info/inf84a_nuclear_development_UK).

<sup>10</sup> According to one of our economist interviewees, the figures in this table are greatly underestimated and the true cost overruns were therefore substantially higher.

<sup>11</sup> Williams (1980) argues that the choice was a manifestation of ‘technological momentum’ that the AEA had managed to build up behind the technology, as well as of the broader desire for home-grown technology.



abandoned since the technology was considered as excessively complex and costly. The government instead recommended the launching of a new nuclear programme, with the AGR and the American-designed PWR. The government of Margaret Thatcher, which came into power in 1979, favoured the PWR design, but nevertheless pursued with the construction of two AGRs and one PWR, which had been approved by the preceding Labour government in 1978.

The choice between coal and nuclear was one of the very key discussion topics in the UK energy policy in the late 1970s and early 1980s, with each energy source supported by its own lobbies (see e.g. Merrick 1976; Pearson 1978; Parker and Surrey 1995). The Thatcher government clearly took side in favour of nuclear, largely in order to reduce the political power of the coal miners' unions.

Despite mounting criticism concerning the cost and risks of nuclear technology, the government announced a new nuclear programme in 1982. Ten PWR reactors, providing a further 15,000 MW of capacity (Greenaway 1992, 130), were to be built, officially to enhance energy security, but allegedly also to crush the political power of the coal miners' union (Hall 1986, 173, in Twena 2006, 12). The first plant was to be constructed in Sizewell, Suffolk, and – in keeping with the environment minister's promise – became the subject of one of the first broad public inquiries in UK's nuclear history (Greenaway et al. 1992, 130). Indeed, the consultation was exceptionally long, lasting from January 1983 to March 1985.<sup>12</sup> Yet the opposition criticised the process for having been a “meeting of closed minds” as the CEGB's construction plans were approved without any major modifications (Kay 2001). The nuclear programme ran into problems also due to technical problems in the AGR plants, the deteriorating relations between the CEGB and British Nuclear Fuels (BNFL), and chronic underestimations in cost calculations (Rough 2009, 18), due in large part to over optimistic assumptions about the future development of technology, but presumably also conscious efforts to hide uncertainties and conceal the total cost of FBRs (e.g. Henney 1989<sup>13</sup>).

### 2.2.3 Plan to privatise the electricity industry...

The changes in the energy policy environment in the early 1980s contributed to a greater emphasis given to market forces in the British energy policy. Energy security concerns declined together with oil prices during first half of the 1980s, the rapidly increasing exploitation of domestic gas and oil resources in the North Sea,<sup>14</sup> and falling uranium prices. In line with the overall government policy of economic liberalism, attempts were made in the UK energy policy to reduce government

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<sup>12</sup><http://www.nationalarchives.gov.uk/catalogue/displaycataloguedetails.asp?CATID=5747&CATLN=3&accessmethod=5&j=1>

<sup>13</sup> Report commissioned by Greenpeace.

<sup>14</sup> Oil and gas had first been discovered in UK waters in the North Sea in the late 1960s, and the first oil crisis made exploration economically viable. In 1978, UK North Sea oil production exceeded for the first time one million barrels per day, in 1981 the production exceeded domestic consumption, and production increased throughout the 1980s and 1990s as a result of new major discoveries (SPICE 2002). Since the late 1990s, especially the gas production has declined and the UK has become a net gas importer.

steering and emphasise instead economic efficiency through the provision of appropriate market signals to consumers and producers. Emphasis was placed upon private enterprise, efforts to introduce market discipline in order to reduce the power of state monopolies, and the need to base investment on strictly commercial criteria instead of security of supply considerations. Furthermore, the explicit government policy did not mention “the strategic significance of periodic fundamental disequilibrium in international energy markets or of environmental or other externalities, the reasons usually given for energy policy” (Parker and Surrey 1995, 821-822).<sup>15</sup>

A more fundamental reform of the energy policy took place only once the Thatcher government entered its third successive term in 1987, making a commitment to privatise the electricity supply industry (ESI) all the while securing the future of nuclear power in the UK. The CEBG – notably its chairman Walter Marshall – continued to express confidence in new coal and nuclear plant throughout 1987 and 1988 in the future privatised ESI, and rejected the need for government subsidies. However, views were divided concerning the structure of the future ESI, with CEBG – flanked by the electricity sector trades unions and the Labour Party energy spokesman John Prescott – strongly opposing the planned splitting up of CEBG into several competing units and unbundling of ownership of transmission network from generation. While a number of independent analysts saw such a fundamental restructuring as a prerequisite of a successful privatisation, the opponents of restructuring – mainly established interests in the industry – argued that restructuring would jeopardise the possibilities of prioritising the nation’s use of resources according to a system of ‘merit order’, and thereby compromise economic efficiency, increase prices and threaten security of supply (Winskel 2002).

The Department of Energy White Paper from 1988, *Privatising Electricity*, proposed to decentralise and remove electricity supply and generation from public ownership (Department of Energy 1988; Nuttall 2005). The plan included three main elements (Parker and Surrey 1995; Winskel 2002). First, ownership of the national transmission grid was to be transferred from the CEBG to a newly created transmission company (known later as the *National Grid Company*) to be jointly owned by the twelve Regional Electricity Companies (RECs) – the former Area Distribution Boards.

Second, generation assets of the CEBG were to be divided between two generating companies (known later as *National Power* and *PowerGen*), with 70% and 30% of the Board’s generation assets, and the National Power owning all the CEBG’s nuclear stations. The old system operating on the basis of ‘merit order’ – aimed at minimising system variable costs whereby the CEBG passed on all its costs, via a bulk supply tariff, to the Area Boards – was replaced by an electricity pool pricing system based on competitive bidding at half-hourly basis. The privatised generators hence had no statutory obligation to supply.

<sup>15</sup> However, Surrey and Parker (1985, 822) remark that despite his apparent commitment to free market, the energy secretary Nigel Lawson praised the large French nuclear programme and expressed confidence in the proposed British PWR programme, “which were the product of central planning rather than market forces”.

Third, to accommodate the high costs and risks of nuclear power, and in recognition of the strategic role of nuclear power in ensuring diversity and security of supply, National Power was given a 70% share of generation, and the distribution companies were required to buy the output of the nuclear stations through a Non-Fossil Fuel Obligation (NFFO).<sup>16</sup> Furthermore, a provision of up to £2.5 billion was introduced in the Electricity Act to cover liabilities for decommissioning existing nuclear stations. Winskel (2002) sums up the thrust of the proposals as that of “transferring power from the production side to the retailing side”. He further argues that National Power was “widely regarded as the privatised successor to the CEGB”, with Lord Marshall appointed as its to-be chairman soon after the publication of the White Paper (Winskel 2002).

It was widely recognised at the outset that due to their poor reliability record and highly uncertain waste treatment and decommissioning costs, privatising the UK’s nuclear power stations would be difficult. Equally difficult under a privatised ESI would be the construction of a series of new PWRs, notably because of their high capital cost. Indeed, a number of independent analysts argued from an early stage that the British nuclear plants were not commercially viable, and should be withheld from privatisation (e.g. Henney 1987; Holmes et al. 1987). Other experts (e.g. Helm 1988) saw no obstacles to the privatisation of the industry along the lines of the White Paper proposals. Indeed, in addressing Parliament, the Energy Secretary Cecil Parkinson indicated in November 1988 that the Government was facing difficulties with the privatisation, because “the question of nuclear economics” was “extremely hard to settle”. In consequence, the Electricity Bill, published later in the same month, while adhering to all of the White Paper proposals, contained an anticipated additional concession to nuclear power – a Fossil Fuel Levy on all electricity bills “to recoup the extra costs incurred by the RECs in meeting the Non-Fossil Fuel Obligation” (Winskel 2002). The Levy was seen as a tacit recognition by the government of the extra cost of nuclear power. Parkinson’s statements from April 1989 represented a further affirmation of the secrecy that had prevailed over the ‘true’ cost of nuclear. While adhering to the view that nuclear power was vital to the diversity and security of electricity supply, he stated that ‘for the first time, as a result of our proposals, the public is being told what nuclear costs are’ (Winskel 2002, 450). Parkinson then went further in his attack on nuclear power under nationalisation, arguing that:

*“The history of the British nuclear programme . . . is littered with appallingly wrong and bad decisions. [...] There was a total lack of financial discipline and management. [...] In the future the generating companies will be able to build power stations only if they can find a customer for the electricity. [...] In the past, because they had the obligation to supply, they decided on the technology, the site, and the size.” (Winskel 2002, 450)*

#### 2.2.4 ...and the withdrawal of nuclear from privatisation

At the end of July 1989, the oldest Magnox reactors were withdrawn from privatisation, on the grounds that the reprocessing and waste treatment costs of spent fuel from these plants would be considerably higher than had “been charged in

<sup>16</sup> Under the NFFO, the RECs were obliged to take 20% of their power requirements from non-fossil fuel sources – in practice mainly nuclear power.

electricity prices and provided for in the accounts of the CEBG and SSEB”.<sup>17</sup> This was still considered insufficient by a number of analysts and some members of Parliament, and in November 1989, the new Energy Secretary John Wakeham declared that all commercial nuclear plants in England and Wales were to be kept under public ownership. All nuclear plants would hence be put under the control of two new public corporations, Nuclear Electric and Scottish Nuclear (Parker and Surrey 1995, 839; Winskel 2002, 450). These decisions essentially meant the cancellation of the proposed PWR programme (as the NFFO would be set at a level not requiring the construction of any nuclear stations), and a moratorium on new nuclear until 1994. As a consequence, Walter Marshall resigned in December 1989 from his positions as the chairman of the CEBG and as the designate chairman of National Power, arguing that his position had become untenable, given the mandate he had been given as the future head of National Power, that is, building new nuclear power in the UK. Marshall vehemently attacked government policy, accusing it for prioritising short-term financial criteria over the long-term good for the society. Marshall argued that the benefits from nuclear power accumulate over a period of half a century, and that it was impossible to introduce new nuclear power into the prevailing environment “driven by short-term market considerations and fierce competition” (Winskel 2002, 451).

Parker and Surrey (1995, 839) recall the reasons given by the government for the policy reversal: the presumably 'unprecedented financial guarantees' that the National Power (still part of the CEBG at the time) was asking as a condition for building new nuclear plants (far beyond the £2.5 billion already provided for decommissioning liabilities), and the revelation of the hitherto hidden cost levels that the attempt to privatise nuclear power had disclosed. Given the cheaply available gas resources, the government was unwilling to provide the guarantees that the National Power / CEBG asked for, in particular since the combined cycle gas turbine technology provided an alternative means of enhancing diversity of supply and reducing pollution, thereby undermining the strategic importance of nuclear power (Winskel 2002). In summary, the size of the potential liabilities threatened to make National Power unsellable without the 'unprecedented guarantees' (Parker and Surrey 1995, 840).

Parker and Surrey (1995, 840) explain how the chairman of the CEBG and of the then embryonic National Power, Walter Marshall, provided far higher cost estimates than before in his evidence to the Energy Committee in 1990, showing levels of nuclear costs two to three times higher than previously revealed and hence totally uncompetitive with fossil fuel generation. The Committee concluded that the CEBG had been guilty of unjustified and sustained optimism in its estimates of nuclear costs over the years. The Committee also criticised the government for having failed to insist on the publication of nuclear cost information and establishing the ‘true’ costs and risks until it was too late to modify the proposed structure of the ESI (HC 205, 1990, para 104-108, in Parker and Surrey 1995, 840). Two years earlier, in July 1988, the Energy Committee had vehemently criticised the privatisation plans as it found no evidence that privatisation would bring down electricity prices, considered government’s plans as excessively sketchy and incomplete and the timetable as

<sup>17</sup> HC Debates, Vol. 157 (1988–89), c746, cited in Winskel (2002, 450).

'frighteningly tight', and thought that 'the nuclear tail seems to be wagging the ESI dog' (HC 307, 1988, paras 41 and 176, in Parker and Surrey 1995, 839).

Walker (1999, 31-32, 38) sums up the economic and financial consequences of the attempted privatisation of the nuclear industry in 1989. The investment in nuclear generating capacity came to a halt, mostly because of the substantial uncovered liabilities in the back-end of the nuclear fuel cycle, notably reprocessing. In order for nuclear to flourish in the private sector, returns on nuclear investment would have had to more than doubled. However, in the privatised electricity sector, the utilities no longer had an obligation to supply; and both the short and long term financial risks were no longer carried by the state but by the new companies' shareholders. Under pressure from the City, the BNFL was compelled to reveal the true costs of reprocessing, including the costs of decommissioning. Finally, the "cost-plus" reprocessing contracts<sup>18</sup> would now be replaced by fixed-price contracts, which would transfer the risks of cost increases to the BNFL.

The consequences of the attempted privatisation of the nuclear industry could be described as that of *changing goalposts for economic appraisal*. As the Energy Secretary John Wakeham argued, the price increases affecting nuclear power did not result from a change in intrinsic costs, but instead from changed accounting practices associated with privatisation. Hence, he remarked that

*'there was no one date . . . that [the technology] changed from being economic to uneconomic...if the CEGB had gone on for another 25 years...the whole thing would have gone along happily without any great drama'.*<sup>19</sup>

The most important changes, Wakeham stated, were the use of 'current' rather than 'historic' costs, and the adoption of a higher required rate of return, or 'discount rate', which made capital-intensive nuclear technology less competitive than fossil-fuel technology (Winskel 2002, 451). In addition, the reassessment of the price of nuclear energy by National Power resulted from a change from *cost plus* to *fixed price* contracts with BNFL. While the cost plus contracts had allowed the BNFL to easily pass on cost increases to the CEGB, to the Area Boards, and ultimately the electricity consumer, the introduction of fixed price contracts prompted the BNFL to greatly increase the prices to National Power in order to minimise its risk exposure. Furthermore, the plant decommissioning cost estimates were increasing dramatically as a consequence of more stringent standards, and the first early experiences of actual decommissioning.<sup>20</sup> According to Parker and Surrey (1995, 839-840), the cost increases that had now come to light represented partly increases in real costs and stemmed partly from changes in the perception and allocation of risks in the context of ESI privatisation. The real cost increases included higher costs of capital, decommissioning and reprocessing, in particular:

<sup>18</sup> In a cost-plus contract, parties had to meet any escalation in costs by paying higher prices for services (Walker 1999, 39).

<sup>19</sup> House of Commons Energy Committee, *The Consequences of Electricity Privatisation: Minutes of Evidence*, HC96 (1989-90), in Winskel (2002, 451).

<sup>20</sup> A detailed analysis of the changing economics of nuclear power in the course of ESI privatisation is provided by Gordon MacKerron, 'Nuclear Power Under Review', in Surrey, J. (ed.), *The British Electricity Experiment: Privatisation: The Record, The Issues, The Lessons*. London: Earthscan, 1996.



- CEGB had used a discount rate of 5% for its nuclear plants under nationalisation, instead of the 10% used by coal and gas industries;
- Magnox decommissioning costs were raised in 1989 from £312 million to £599 million per station – an increase of £2.3 billion for all eight of the CEGB's Magnox stations (HC 205, 1990, para 19);
- Over the ten years to 1988, Magnox reprocessing costs had risen fivefold because of more stringent safety and environmental regulations which necessitated heavy expenditures by BNFL;
- Policy until 1988-89 had not envisaged decommissioning and clean-up of Sellafield. When the policy was changed (in the run up to ESI privatisation) the accumulated provisions were far too small and, since there was no experience of nuclear decommissioning, large contingency allowances were added to the estimated engineering costs.

In anticipation of privatisation, the shareholders got a flavour of the risks they would be faced by with a privatised nuclear industry – risks whose costs had thus far been passed on to the consumer or carried by the government. These included risks of “nuclear accidents (to the extent the full liability was not covered by the state), variable reactor operating performance, continued tightening of safety and environmental regulations leading to design modifications, retrofitting or capacity de-rating of reactors, and the possibility that decommissioning might be required to take place as soon as sufficiently safe rather than after a delay of 100 years or more” (Parker and Surrey 1995, 840).

Meanwhile, in his evidence to the Energy Select Committee in mid-1990, Walter Marshall continued to argue that, fundamentally, both AGR and PWR technologies remained economical, but that the withdrawal of nuclear power from privatisation reflected weaknesses in the government's proposals rather than the economic failure of nuclear technology. Had the government decided to retain generator's obligation to supply, the PWR programme could have progressed successfully alongside investment in combined-cycle gas turbine plants (Winskel 2002). The privatisation plans triggered diverging assessments also from different independent experts, as reported by Winskel (2002). While some argued that privatisation was quite viable and that the government should have accepted to provide the guarantees required by National Power – simply as the price to pay for privatisation – others maintained that a privatised industry would be neither able nor willing to carry the risks and uncertainties involved. Lazard Brothers, investment advisors to CEGB/National Power, told the Energy Committee that their advice had always been that privatising nuclear was very problematic, due to ‘unlimited liabilities’ arising from waste fuel management and plant decommissioning, as well as the numerous risks, most of which they regarded as unquantifiable.

Eventually, after the debates and policy reversals involved in the preparation of privatisation, the process proceeded relatively smoothly after 1989. The entire nuclear industry was retained in public ownership, but successfully floated in the financial market. With the entire nuclear industry retained under public ownership, National Power, PowerGen, National Grid, and the Regional Electricity Companies were vested at the end of March 1990, and successfully floated between December 1990 and March 1991 (Winskel 2002, 452).

After privatisation, while the nuclear industry continued to enjoy market guarantees and subsidies, it was placed under much greater commercial pressures than ever before. Under such pressures and scrutiny the nuclear industry improved its technical and economic performance: more economical AGR reactors were introduced, the three oldest Magnox reactors were shut down, more commercial accounting and management practices were introduced, staff levels were drastically reduced, and more attention was given to and experience gained on decommissioning. Encouraged by this improved performance, the government planned in 1995 to privatise as a single company the seven AGR nuclear power stations belonging to Nuclear Electric and Scottish Nuclear, as well as the Sizewell PWR. At the end of 1995, the thereby created *British Energy*, still in state ownership, announced that it would not proceed with the early construction of any new PWR plants – an announcement that was reported as a death knell to the UK nuclear programme (Winskel 2002, 454). To justify its withdrawal, British Energy evoked commercial reasons and government's refusal to provide funds for the construction. Independent analysts, in turn, argued that the BE's decision reflected the judgement that private investors would not be keen to invest in a company that would build new nuclear plants. In mid-1996, British Energy was successfully floated, but in the absence of strong economic and financial incentives (e.g. carbon tax) and with the waste disposal risks remaining significant, prospects for new nuclear stations were bleak (Winskel 2002, 454).

### 2.3 Summary of the evolution of the UK nuclear sector

The commercial UK nuclear programme encountered serious technical and economic problems since its beginning in the mid-1950s. These technical issues and cost overruns gradually eroded AEA's credibility over the next two decades. Hence, the UK already had experience of the ways in which very optimistic initial expectations about the potential of a technology can deepen the disappointment and disillusionment once the expectations fail to come to fruition. This experience contributed to the difficulties of the AEA to push forward the fast breeder programme during a critical period in the 1970s. Arguably, the public and especially political/industry support for fast breeder reactors was weaker than it would have been, if the experience with thermal reactors had been more positive. The wrangling and indecisiveness concerning the choice between competing reactor designs in the 1970s was a particularly serious handicap for the industry as a whole. The slowly emerging 'discourse of fear' around nuclear energy was buttressed by increasingly critical media reporting. In 1983, a TV programme revealing child leukaemia rates twelve times the national average among Sellafield families led to media and public demands for an investigation (Dalquist 2004, 22; Twena 2006, 16). The earlier positive and enthusiastic media reporting was by the 1970s increasingly replaced by critical accounts by environment journalists, echoing views from the rising environmental movement. According to Williams (1980, 337-338, in Twena 2006, 15), the period between 1975 and 1978 was a turning point in media activity, as for the first time there were "innumerable" radio and TV debates, as well as several major public seminars and hearings on the topic. Public inquiries for the first time exposed the economic, technical and safety problems involved in the use of nuclear power. Parliament gradually emerged as an actor in decisions concerning nuclear energy

(Twena 2006). While the public opinion remained predominantly positive towards nuclear energy (Rough 2009), the AEA and the nuclear industry, notably the BNFL, were greatly weakened by the rising public doubt and opposition (Twena 2006). The financial sector actors gained a central position at this period, while, despite the rising public fear and scepticism, the anti-nuclear NGOs remained weak.

Finally, the entry in power of the conservative government of Margaret Thatcher proved to be a crucial turning point. While Thatcher had a generally positive attitude towards nuclear power, her primary objectives were political and ideological: fast breeder reactors would be acceptable or even desirable, on the condition that they were financially and economically viable within the framework of a liberalised market. Since fast breeder reactors would not be useful in breaking the power of the coal miners' unions – one of Thatcher's primary political objectives – they stood little chance of obtaining government support under Thatcher era. The privatisation of the electricity industry and the failed attempts to privatise the nuclear industry in 1989 revealed the financial and economic risks associated with privately operated nuclear plants. Once the industry came under the economic appraisal by the City its reputation as a cheap source of electricity dissipated, and the privatised industry had no incentive to build new plants. Winskel (2002, 457-458) sums up the consequences that the changing of goalposts of economic appraisal caused for the nuclear sector. Subject to new economic and regulatory imperatives, the individuals and institutions advocating nuclear power were marginalised, and were unable to impose any preferred technology on the industry, and the "arbiters of technology investment were no longer engineers, but rather investors and shareholders who employed financial rather than technical criteria". This process whereby the nuclear industry and the organisations promoting nuclear power gradually lost their autonomy and political power also eroded the confidence and support for fast breeder reactors.



### III. THE FAST BREEDER REACTOR DREAM: EXPECTATIONS FOR THE FUTURE

**Figure 4: UK Nuclear fast breeder timeline**



Sources: Patterson (1985; 2010); AEA (2004).

### 3.1 FBR as the long term goal

Research into fast breeder technology began in the late 1940s, almost as early as fission research. Although no dedicated FBR programme existed in the 1940s and 1950s, there was a strong interest among scientists and engineers to develop a reactor that could potentially revolutionise nuclear energy production with its efficient use of uranium and reduced generation of waste. Furthermore, the expected scarcity of uranium resources enhanced the support for the future development of fast breeders.

*“On a long-term view the main argument for U-235 was that it was needed for research and development on the most promising future nuclear power development – that is, fast neutron reactors with no moderator operated with concentrated fissile material instead of natural uranium. These reactors would produce power and also produced more fissile material than they consumed. Any large-scale exploitation of atomic energy must, it was thought, ultimately depend on this breeding. Development in this field would involve a considerable research programme which would be dependent on the possession of an appreciable amount of fissile material in rather concentrated form” (Gowing 1974, 177).*

This underlying conviction about the “unavoidability” of fast breeders as the cornerstone of nuclear energy was confirmed by our interviewees, and perhaps best encapsulated in a statement of a former AEA scientist: “anyone who is really thinking and is looking for a world role over hundreds of years for nuclear power, if they haven’t got fast reactor in their thoughts, it’s because they haven’t thought enough”. At the political level, this belief was expressed for instance in the first report of the Select Committee on Science and Technology, published in October 1967, which was very optimistic about the future of FBRs as the key pillar of nuclear energy (Patterson 2010, 75).

The British strategy of developing nuclear power advanced along a two-track route. The first one was to reach the immediate nuclear power and military goals by using existing competencies and knowledge from the thermal reactors developed early on in the atomic programme. However, since thermal reactors were viewed as an interim solution, ultimately to be taken over by FBRs, the second track entailed the development of a long-term programme for fast breeder research. The assumption that plutonium-fuelled fast breeder reactors would be “the key to any long-term civil nuclear programme” prevailed among the British nuclear establishment (Patterson, 1985; Ham and Hall 2006). This view, affirming the urgency of fast breeder development in the UK, was encapsulated in a statement made in 1977 by Burt Cutts, Head of Central Technical Services at AEA’s Risley research institute (Cutts 1977):

*“Any nuclear programme which relies exclusively on thermal reactors and therefore on a continuing large uranium supply will thus be increasingly at risk to increased prices and to a potential interruption of supplies. In the UK it would imply a renewed commitment to large-scale importing of energy from abroad at the expense of foreign exchange – a situation from which North Sea oil is about to rescue us, though on a*

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*temporary basis. The fast reactor will release us from this burden for the conceivable future and its successful development is more urgent than is sometimes argued.”*

### 3.1.1 Dounreay Experimental Fast Reactor, DFR (1950s to mid-1960s)

Three years prior to the setting up of the AEA, initial steps were taken to establish the fast reactor programme, as the Fast Reactor Design committee held its first meeting in October 1951.<sup>21</sup> This committee would meet sixty-five times in total over the seven-year period from October 1951 to November 1958. They scrutinised 277 papers, reports and drawings, “mostly all written in great scientific and engineering detail, many accompanied by bewildering equations and formulae.”<sup>22</sup>

Despite the doubts and hesitations notably among the Risley engineers, at the official level the trust in fast breeder technology as the future of nuclear energy gained strength. Therefore the construction of an experimental fast breeder power station started in March 1955 at the AEA's new Dounreay Experimental Reactor Establishment, at an abandoned war airfield on the north coast of Scotland (Patterson 1985, 98). The remote location was chosen largely because of the accident risks<sup>23</sup> (Patterson 1985), and also because in an economically declining region that was losing its young population, an industrial project of the calibre of the DFR was welcomed by local politicians and populations (Brown 2007; AEA interview).<sup>24</sup> The Dounreay site had two reactors, the Dounreay Materials Test Reactor (DMTR) and the Dounreay Fast Reactor (DFR). Over a period of more than three years, as many as 3000 persons worked at the various installations on the site, including fuel fabrication plants, a plant for reprocessing the fuel from the DFR, laboratories, waste stores, workshops, and offices. About half of the personnel were locals from Caithness (Brown 2007).

Both the construction and operation of the DFR were plagued by a series of technical problems as well as unexpected external events. Work at Dounreay was stalled because of the Windscale fire, preventing the DFR from going critical until 1959, two years behind the schedule. In August 1961, the reactor reached an output of 1.5 MWt – a fraction of the expected 60 MWt. The output increased to 11 MWt in December the same year. But progress was halted again when the reactor had to be shut down to

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<sup>21</sup> Committee members included Sir John Cockcroft, Sir William Penney, R.R. Matthews (to become Dounreay's second director), and C.R. Tottle, who later became head of reactors at Dounreay.

<sup>22</sup> <http://www.caithness.org/fpb/dounreay/history/fastbreeder/>

<sup>23</sup> Patterson (1985, 98) describes how, in its first annual report from 1956, the AEA notes that an “accident in the reactor might lead to a rapid rise in temperature which in turn might cause the melting of the fuel elements. If this should happen there might be an escape of fission products from the core.” To avert the risks a 140 feet steel dome was placed over the reactor.

<sup>24</sup> Brown (2007) describes the expectations of local populations at Dounreay as follows: “Fishing, flagstone industry and agriculture were all in decline and mechanisation was reducing the labour force required. Caithness had long been exporting its major asset – people. Establishing the UK's Fast Reactor project at Dounreay changed all that – it brought back exiles and introduced a new breed of resident – the Atomics.” She further notes that Dounreay faced competition from another site in Speyside, but that “heavy rains and strong winds on the day of the official visit turned the decision in favour of Dounreay!”

allow the replacement of the fuel core with an upgraded design. In July 1963, the DFR reached its maximum output of 60 MWt (Patterson 2010, 74).

Opinions diverge on the success of the reactor once in operation. Herbert (1962) evoked the numerous difficulties faced during the early years of operation of the DFR, most of which were associated with the sodium coolant system (e.g. formation of oxides and hybrids, which resulted in frequent blockages in the reactor). Herbert repeated the argument that would in the subsequent years be frequently evoked by FBR advocates: most of the problems were mechanical – the people responsible for the working of the reactor emphasised that the physics of the reactor had “gone like a dream”, and the ‘bugs’ at Dounreay had been involved with attempts to get the heat away from the core, not in producing it. Herbert considered that the end of the engineering troubles was finally “well within sight”. As a consequence of the experience from the DFR, some of the equipment in the prototype reactor would be simpler, because a lot of the problems with the DFR could be attributed to the existence of complicated automatic machinery. Finally, Herbert considered the challenges faced by the construction of a commercial reactor: in particular, finding a suitable site for the reactor and connecting it to the grid would not be easy.

While Judd and Ainsworth (1998, 609) refer to the “inevitable teething troubles” notably during the construction of the reactor, they argue that once the reactor was in full power, “things went very smoothly”, the reactor being “stable in operation” and “all the major components” working with little trouble. They nevertheless recognise, as the “only major interruption”, a leak in one of the main primary coolant pipes – which did not cause significant release of radioactivity, but was difficult to repair (ibid.). Simnad (1998, 528) provides an equally positive overall judgement of the performance of DFR, noting that the “reactor served as a most productive test-bed that led to many important advances in FBR technology and MOX fuel”. He highlights in particular the discovery made in the DFR in 1966 “relating to the phenomena of irradiation swelling and creep in stainless steel cladding”, which “led to the development of advanced fuel and structural materials for FBR cores.”

By contrast, Patterson (1985, 101) deems these problems as significant, noting that 500 damaged elements in the outer breeder section had to be removed, and special cutting tools and removal equipment had to be manufactured to do the work. In May 1967, the DFR primary cooling circuit leaked but the AEA said reassuringly that the molten sodium leak was small. Only a few months later, in July, the DFR was shut down for a period of more than a year, until June 1967. In 1966, the phenomenon of irradiation swelling due to neutron-induced ‘voidage’ in stainless steels was discovered – a problem that was to cause major headaches for the engineers and scientists working on fast breeders, and have a profound effect especially on the development of fuel and structural materials for fast reactors (Judd and Ainsworth 1998, 611).

Although far from reaching its expected output and marred with problems, the DFR became the world's first fast breeder reactor to provide electricity to the national grid (UKAEA 2006). Even critics such as Patterson (1985, 114) acknowledged that “Britain could claim with justice in the 1960s that it led the world in fast breeders.”

The DFR was intended as an essential early step towards a large 1000 MWe commercial FBR, expected to go online by the 1980s. In pursuit of this objective, the AEA pressed forward towards the next design stage, the Prototype Fast Reactor (PFR).

### 3.1.2 Prototype Fast Reactor, PFR (mid-1960s to 1970s)

During the second nuclear programme in the mid-1960s, alongside with the development of the AGR design, the AEA was also drawing up designs for a new prototype fast breeder reactor. The PFR was intended for commercial use, with an expected output of 600 MWt – equivalent to 250 MW electricity. In August 1965, the AEA was already drawing up detailed designs for the plant and civil engineering contracts, well ahead of the official approval for the PFR in February 1966 (Patterson 1985, 99). Scientific exchange through a series of international conferences ensured that PFR was very similar to prototype reactors in other countries, including the Phénix in France and BN-600 in Russia (although the latter was considerably larger) (Judd and Ainsworth 1998, 611). According to Judd and Ainsworth (1998, 613) the collaboration with the US was particularly fruitful in the development of the prototype reactor.

The AEA would have wished to place the PFR in a less remote location – to demonstrate the innocuousness of the reactor and to avoid long and costly transmission of electricity from a remote production site to consumers. However, seeking to win a seat in the upcoming elections, the Labour government had already decided to place the PFR in Dounreay, which already had a pilot reprocessing plant. But the separated plutonium would still need to be transported to Windscale for fuel fabrication. The government was also keen to keep the jobs in Dounreay, where fast breeder R&D had given a major stimulus to the local economy.

#### 3.1.2.1 *Delays and technical problems*

Numerous problems and delays were encountered in the construction of the PFR. One of the first difficulties concerned the complex rotating 'roof' of the reactor, which proved much more difficult to fabricate than the AEA had anticipated. While conceding that the roof construction problems would delay the entry in service of the PFR beyond the foreseen date of 1971, the AEA considered the problems of conventional engineering nature, and unrelated to the fast breeder aspects (see e.g. Valéry 1974). Nevertheless, the early years of operation of PFR were marred by many leaks in the steam generators due to 'stress-corrosion cracks' (Judd and Ainsworth 1998, 613; Brown 2007). Formidable challenges were faced by AEA scientists and engineers trying to find materials able to withstand the demanding environment in the fast reactor core, notably to prevent the so-called void-formation problem.<sup>25</sup> Presumably some of the technical problems were caused by the desire to prepare for

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<sup>25</sup> The problem stemmed from the intense high-energy neutron radiation for lengthy periods that the structural materials containing and supporting the fuel had to resist. Hence, the “fast neutrons knocked atoms out of place in the stainless steel, leaving 'voids' that weakened the crystal structure and deformed the components made from it” (Patterson 1985, 102).



the scaling-up from the PFR directly to a commercial reactor by building the PFR as a “big reactor run small” (Valéry 1974, 424). Hence, for example the fuel configuration was optimised for 1000 MWe rather than 250 MWe, and the primary pumps and other components were designed to “oversize” in order to facilitate the scaling-up (ibid.).

The late 1960s was a period of great expectations and firm faith in fast breeder technology as the logical final objective of the development of nuclear energy. The mounting expectations gave further impetus to the PFR project. The Select Committee on Science and Technology, in its October 1967 report, expected the 250 MWe prototype to be on power in 1971. In 1969 the AEA stated that it would start building commercial FBRs as quickly as possible once the PFR would be in operation. For the government, FBRs would be “the major event of the rest of the century” (Patterson 1985, 101). The AEA remained confident. Hawkes (1971, 682) reported on an optimistic declaration by R.V. Moore, head of the AEA's fast reactor effort: *“We're into the finishing straight. Testing and commissioning starts early next year and criticality is expected towards the end of 1972. We're not going to rush the start-up program.”*

The PFR did not go online as expected by 1971. The sodium pumps were failing to perform during a test in 1973. The reactor finally reached criticality in 1974, opportunely just a week before the start of a high-profile international conference on 'Fast Reactor Power Stations' hosted by the British Nuclear Energy Society. The conference, attended by a number of European countries – notably France – the US, the Soviet Union and some developing countries, became a stage for an Anglo-French rivalry in nuclear technology. At the end of the conference the French announced that their Phénix fast breeder had just attained full power. According to Valéry (1974, 424), the PFR had cost £20 million less than Phénix, but had on the other hand taken considerably longer to build. Conference papers hailed the FBR success and downplayed the technical difficulties (Patterson 1985, 105). However, at least one significant dissenting voice was heard in the conference, from the CEBG.<sup>26</sup> The CEBG argued in particular on the basis of assessments concerning the economic viability of fast breeders. The CEBG hence noted that the savings from FBRs would hardly be greater than 5% of the overall costs of a nuclear system, and even this only in “the unlikely event of capital costs of fast and thermal reactors being equal” (Patterson 1985, 105). The CEBG contributors estimated that FBR orders could not be placed before 1977-1978 (Patterson 1985, 105).

The AEA continued the work at Dounreay, undisturbed by the CEBG's scepticism. But small leaks occurred in 1974 in the steam generators – a complex boiler system where hot molten sodium flowed through thousands of tubes in order to boil water. The leaks were problematic due to sodium's reactivity with water. Eventually the problem parts had to be taken out of the reactor in order to plug the leaks. Yet the AEA claimed that the reactor itself was stable and performed well, and that the numerous problems encountered only concerned ‘ancillary’ elements or the ‘conventional’ part of the plant (Judd and Ainsworth 1998, 612; Brown 2007), such as the secondary sodium circuits, the steam system and the materials used to build the

<sup>26</sup> Presentation by Eric Carpenter, head of reactor physics at the CEBG's Berkeley Nuclear Laboratories.

units (Valéry 1974; Judd and Ainsworth 1998, 612; Patterson 1985, 106). Hence, the argument by the AEA and other FBR advocates was that “the reactor itself was stable and predictable” (Brown 2007). The reactor itself was “a model of good behaviour” (Valéry 1974, 424), and the difficulties were “minor” (Kenward 1974, 425) and not inherent to the fast breeder technology (Patterson 1985, 106), and that the “small leaks” that had appeared were considered as “nothing as hazardous” (Valéry 1974, 424). Simnad (1998, 528-529) acknowledges the problems – the extension of the construction time because of “difficulties in welding the large reactor roof and in making the tubeplate welds in the steam generators”, as well as “delays to accommodate new information on neutron-induced swelling of the stainless steel cladding and core structural components.” Furthermore, Simnad argued that even these minor problems had been effectively solved by the late 1990s.<sup>27</sup> However, not only does Simnad echo the view that the technical problems concerned only the conventional part of the plant, but uses a similar argument also to reassure those concerned about safety:

*“accidents and safety issues have related to non-nuclear components of nuclear reactors in general and FBRs in particular, and that all concerns will be adequately addressed with the successful design of passively safe nuclear reactors, which should be immune to the types of failures that occurred at Chernobyl and at Three Mile Island”* (Simnad 1998, 523).

Symptomatically, Valéry (1974) attributes most of the delays at Dounreay (PFR) to what he calls “the traumatic reorganisation” that according to him had “been racking the British nuclear boiler and heavy electrical industries over the past six years”. Halfway through the project, the responsibility for the construction of the PFR was surrendered by the AEA to the industry (TNPG). Valéry further argued that the on-going merger of the two nuclear constructors – TNPG and the British Nuclear Design and Construction – into Nuclear Power Company would lead to the desirable situation in which all crucial experience would reside within the industry itself rather than within the AEA alone.

### 3.1.2.2 *Set-backs in public relations*

The technical problems encountered by the PFR were compounded by embarrassing public relations failures. Since the rest of the reactor seemed to be behaving well, the AEA organised a major press visit, flying some seventy journalists to Dounreay on 30 October 1974. The visit turned out to be devoid of much journalistic interest, leaving the journalists wondering about its purpose. Apparently, the AEA had planned to connect the PFR to the national grid on that day, but a fierce storm in the North Atlantic the preceding week had apparently uprooted hundreds of tonnes of seaweed, which had been sucked into the reactor's cooling-water intake, forcing a shutdown of

<sup>27</sup> “For example, small leaks in the evaporators led to the insertion, brazing and explosive welding of sleeves in the ends of all 3000 tubes, which proved to be a very effective solution. The reactor itself operated almost faultlessly, with a stable and predictable performance. The irradiation distortion of the fuel assemblies was minimized by rotating them periodically during their irradiation lives. Fuel burn-up targets were eventually increased to 20% with high nickel cladding. The very few fuel pin failures in the PFR behaved in a very benign manner, so that operation of the reactor could continue until the next convenient shutdown.” (Simnad 1998, 528-529)

the reactor until the seaweed could be cleared away. To avoid embarrassment, the AEA chose not to say anything about the event to the journalists (Patterson 1985, 104).

Another unfortunate PR setback occurred at the end of April 1975, during a site visit to Dounreay following the inaugural conference of the newly-formed European Nuclear Society in Paris. A month earlier the reactor had generated its first electricity, but consistent trouble with the cooling system and turbine bearings had prevented the PFR from reaching more than 12% of its full thermal capacity. The AEA staff argued that the reactor was working fine; however, just before the visit of the European nuclear experts, small leaks appeared in a section of the only operative cooling circuit – a source of further embarrassment to the AEA (Patterson 1985, 104).

In 1975, the PFR operated on average at only about one-tenth of its full power. Even voices within the international nuclear energy community remained sceptical, with the *Nuclear Engineering International* predicting in February 1976 that the PFR would not reach its full power until several months. The same publication finally reported somewhat better news in September 1976, noting that during most of the previous month, the PFR had been "operating on all three of its coolant loops with all of the early heat exchanger problems now remedied." The publication expected the reactor to reach full power by the first week in September, but at the same token implied that the reactor was still a long way from demonstrating that fast breeders could fulfil what Patterson (1985, 107) describes as "the CEGB's requirements that they be reliable, built on schedule and within budget."

Yet the AEA continued to press forward. In 1977, there was an explosion in a disposal shaft for contaminated waste. The experimental reactor, DFR, was closed in March 1977 – as a further indication of the AEA's confidence in PFR's performance. Hinton also supported the FBR stating that the AEA would build a full-scale fast breeder "not later than the end of this year [...] the aim should be to commission it before 1985". However, leaks and technical problems persisted, and the PFR's capacity factor remained at an average of about 10% during the first ten years after starting up (Patterson, 1985, 108). Yet, while recognising the low load factor during the first half of the PFR's lifetime, Judd and Ainsworth (1998, 612) point out that the load factor improved greatly after 1984, reaching 80% in its final operating year, 1994 (Simnad 1998, 529).

### 3.1.2.3 *PFR in balance: a success after all?*

The PFR failed to meet the expectations on its performance and capacity factor, a fact eagerly pointed out by its critics. Patterson (1985, 101-108) disparagingly called the PFR "the ten-percent reactor", referring to the analysis published in October 1984 in *Nuclear Engineering International*, which estimated the total lifetime capacity factor of the reactor for its ten first years of operation at 9.9%. The AEA, by contrast, considered that the project had made some "major contributions" to the UK fast reactor project. The fast breeder advocates have consistently argued that the technical problems associated with the functioning of the PFR were a matter of "conventional materials physics" rather than being linked with the fast breeder technology (see e.g.



Judd and Ainsworth 1998; Brown 2007).<sup>28</sup> The positive contributions of the PFR included the demonstration that it was possible to achieve a fully closed nuclear fuel cycle from breeding of plutonium, through its separation through reprocessing and finally to its use for manufacturing fresh fuel – all within the same reactor (Brown 2007). Judd and Ainsworth (1998, 613) consider the PFR to have been “a test facility for the improvement of fuel performance”, as the fuel burn-ups improved from the original 7.5% to as high as 20% (see also Brown 2007). Hirsch and Farmer (1986, 297-300) present the AEA view on technical performance, noting that the UK plant demonstrated the viability of “the basic PFR plant design style with all the primary circuit components in a single tank”, deeming it likely that this solution would “be adopted throughout Europe”. In their view, the “large scale operational experience” had helped validate calculation methods and data concerning “reactor and fuel performance, control and safety, materials properties and design codes” (ibid.). Importantly, the authors claimed that sodium had “proved a highly satisfactory coolant, capable of being used with high temperature, high thermal efficiency steam cycles”, adding that “[e]ven its disadvantage of opacity has been minimised by the development of ultrasonics based under-sodium viewing devices.” While acknowledging the “considerable problems with water leaks from welds in the steam generator, which reduced station availability”, they underline the achievements, including the advancements in burn-ups (11% in standard fuel, 13% in experimental fuels and the future prospects of up to 20%), demonstration of reprocessing to a high standard of safety, plutonium accountability and effluent discharges, and the presumably low fuel cycle costs – approximately 70% of those for PWRs with the “very low” uranium prices prevailing at the time.

Judd and Ainsworth (1998, 613) also underline the “significant contributions” the PFR made to reactor safety, including the demonstration that the reactor posed very low radiation hazard and that in the event of complete failure of the coolant pumps, natural convection of the primary sodium would remove the decay heat without excessive temperatures in the core. Furthermore, Judd and Ainsworth (1998, 613) stress as a particularly strong demonstration of safety the fact that the safety case withstood “careful scrutiny against the criteria applied to commercial thermal reactors”, as the reactor was for the first time licensed by the Nuclear Installations Inspectorate (NII), in 1991. Indeed, at the time of the creation of the AEA, no licensing regime for nuclear sites existed in the UK. Such a requirement was only introduced with the Nuclear Installations Act in 1959, as recommended in the report into the Windscale fire two years earlier (HSE 1998, 1). The Act stipulated the setting up of a Nuclear Installations Inspectorate (NII), and contained provisions for the licensing of users of nuclear installations (ibid.). However, the AEA – and therefore also the fast breeder reactors – was exempt from the licensing requirement until 1990, when it was brought into the licensing regime, now governed by the newly formed Health and Safety Executive, HSE (ibid.). The Scottish Environment Protection Agency (SEPA), established

<sup>28</sup> A newspaper article from November 1993 (Buchan 1993) reports that according to the PFR operations manager, Derek Shipley, “[f]or an experimental reactor, Dounreay has worked... pretty well”. The newspaper continues explaining the argument of Shipley, according to which the problems at the site would have “little to do with the physics of the small machine sunk in the Caithness granite, but in the transfer of its generating force to the light-bulbs and washing-machines of the Highlands. Operators have had continuous difficulty actually making electricity.”

in 1996, has specific duties with respect to radioactive substances and will assume a regulatory role for the more severely contaminated land sites, including Dounreay (ibid.).

Hirsch and Farmer (1986, 297-300) argue that “the inherent safety characteristics of sodium-cooled reactors” have been proven both in the UK and in the USA. Hirsch and Farmer likewise evoke the capacity of FBRs to prevent over-heating by natural convection alone, in what they consider an extremely unlikely case of all coolant pumps failing simultaneously. They also refute as “unfounded” the “theoretical fears about very large energy releases from interactions between severely overheated fuel and the sodium coolant”, underline that FBRs produce very low radiation exposure to staff, and argue that these favourable safety features provide protection against escalating costs in case radiation standards were tightened up in the future. Finally, Hirsch and Farmer note that the activity levels in effluents have been consistently very low, throughout the operation of the PFR lower than those authorised originally for the reactor, even though the activity handled had increased by tenfold and plutonium by thousand-fold.

## IV. THE LONG DECLINE

The early 1970s marked the beginning of the decline of support for fast breeders in the UK, resulting from a combination of factors such as the split-up of the AEA, an increasing scrutiny of the economic and financial performance of fast breeders, mounting technical problems in the prototype reactor, declining uranium prices, and rising public opposition largely fuelled by nuclear accidents such as those in the Three Mile Island (1979) and later in Chernobyl (1986).

### 4.1 AEA split-up and the erosion of institutional support for fast breeders? (1970s)

A crucial change in the UK nuclear establishment took place in 1971, when the hitherto uncontested leader of the country’s nuclear policy, the AEA, was split up into three separate organisations. While the AEA had until the beginning of the 1970s virtually a free reign to develop its own R&D in the directions of its own choice, the splitting up of the organisation began a new era of increasing government oversight and accountability. After the reorganisation, the AEA only retained research activities, while the Radiochemical Centre Ltd (later Amersham plc) took over production of medical and industrial radioisotopes, and the British Nuclear Fuels Ltd (BNFL) was given the responsibility for nuclear fuel and weapons material producing activities. The BNFL therefore became the manager of the manufacturing plant at Springfields, the enrichment plant at Capenhurst, the spent-fuel facility at Windscale, and the dual-purpose Calder Hall and Chapelcross military plutonium producing reactors.<sup>29</sup> Patterson (1985, 17) casts doubt on “the ostensibly commercial nature of BNFL”, on the grounds that the AEA held 100% of the shares in BNFL, and that AEA chairman Sir John Hill was also installed as chairman of BNFL. Furthermore, he refers to the essentially non-commercial nature of the production of fissile material for British

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29 [http://www.world-nuclear.org/info/inf84a\\_nuclear\\_development\\_UK.html](http://www.world-nuclear.org/info/inf84a_nuclear_development_UK.html)

nuclear weapons - an activity whose financial basis was kept out of the 'commercial' books (Patterson 1985, 69).

As a result of the changes, while still owning and operating the PFR (as well as the associated fuel fabrication and reprocessing plants and the supporting development facilities), the AEA no longer had the complete responsibility for the project. The PFR was designed by the Nuclear Power Group (TNPG), which was subsequently transformed and renamed the National Nuclear Corporation (NNC). The project was government-funded, but the BNFL and the main nationalised nuclear utilities, the Central Electricity Generating Board (CEGB) and the South of Scotland Electricity Board (SSEB), were represented in the management of the project and contributed to the R&D work (Judd and Ainsworth 1998, 614).

#### **4.2 Towards a commercial fast breeder reactor (CFR) and international collaboration (1970s)**

In the early 1970s the AEA was pushing the government to approve the construction of a Commercial Fast Reactor (CFR), which was to be a scaled-up version of the PFR – a 3300 MWth, 1320 MWe oxide-fuelled pool reactor, designed by the NNC (Judd and Ainsworth 1998, 614). The first British design study for a 1000 MWe commercial fast reactor was produced during the first half of the 1960s (Valéry 1974, 424) and the design of a commercial reactor started at earnest in the early 1970s, during the time when the PFR was still under construction. The reference design of a 1300 MWe reactor, CFR-1, produced by TNPG, emerged in 1973. At this time, about 39% of UK public funding of energy R&D went to fast breeders, while the corresponding figure in France was about 30% (Surrey and Walker 1975, 93). By 1976 the AEA was spending on FBR R&D only – excluding investments – close to £100 million per year (Patterson 1985).

However, the launching date for a commercial reactor was repeatedly pushed forward. In 1970, the AEA Chairman John Hill expected the construction of a prototype to start in 1974, a view reiterated in the AEA annual report 1971 (Patterson 1985, 103-104). In its monthly magazine, the *Atom*, the AEA in February 1973 estimated that, on the basis of the experience and know-how acquired through the PFR, a commercial FBR programme would be viable, with a lead station coming on line in 1981 and further stations in the mid-1980s. The AEA expected the first order to be placed in around 1976. Patterson (1985, 104) points out the high, if not excessive, ambition of this schedule: the CFR would be constructed and running in five years whereas the AGR required over eight years to complete. In a presentation delivered in the US in 1973, the deputy managing director of the AEA's Reactor Group, Tom Marsham, stated that there was “nothing adventurous or foolhardy about” the AEA’s plan, given the “[s]atisfactory experience with the experimental reactor DFR in the early 1960s”, and the subsequent construction of the PFR (Patterson 1985, 104).

Patterson (1985, 104) suggests that the optimism of the AEA reflected the degree to which the organisation was out of touch with the political and economic realities of the time. In particular, he argues that the AEA refused to see the trouble in which the country's nuclear policy as a whole found itself at the time. Patterson (1985, 104)

hence enumerates the numerous reasons that would have, in his view, warranted a more cautious approach to FBRs:

*"the Dungeness B was in chaos; the later AGR stations were already falling behind schedule. The consortia had dwindled to two; the choice of reactor for forthcoming nuclear stations was under examination in the secret and eventually fruitless deliberations of the Vinter committee."*<sup>30</sup>

In parallel with the Vinter committee examination of thermal reactor policy, another committee was examining UK's fast reactor policy. Again, the findings were kept secret, but they arguably underpinned a policy statement made on 8 August 1972 in front of the House of Commons, in which the then Secretary of State for Trade and Industry, John Davies, announced that the government wanted 'to push ahead as rapidly as possible with development of the fast reactor' (cited in Patterson 1985, 103-104).

However, while the AEA continued, at least until 1977, to press for quick development of commercial fast breeder reactors, there were sceptical voices for instance in Parliament. For instance, the House of Lords Select Committee on the European Communities,<sup>31</sup> when gathering evidence on the 'EEC Energy Policy Strategy' R/3333/74 in the spring of 1975, considered that the EC Commission's proposals on nuclear energy were "not realistic" (Patterson 1985, 115).

In the mid-1970s the ranks among the fast breeder advocates slowly began to loosen, as the subtle changes in the views of Walter Marshall, at that time the Department of Energy's chief scientist and Harwell's director, demonstrated. On the one hand, Marshall was hesitant about whether the UK should continue developing its own fast breeder programme or instead join efforts with other European countries in fast breeder development – as suggested by the above-mentioned Commission reports. Even more crucially, Marshall expressed doubts about the rate of development of a commercial FBR, predicting that, in contrast with the optimistic forecasts from the 1950s, the UK would "have only two fast reactors operating at the turn of the century at the present rate of progress" (Patterson 1985, 115). Marshall's scepticism reflects a more general cleavage between the AEA and the CEGB, with the latter far more interested in quickly launching a thermal reactor programme than in pursuing the much longer-term R&D effort into fast breeders. Marshall was indeed one of the main proponents behind the introduction of PWRs in Britain (Patterson 1985).

<sup>30</sup> Faced with the apparently intractable problem of reactor choice between the AGR and PWR, the Conservative government of Edward Heath set up, in 1971, a committee chaired by Peter Vinter, a deputy secretary in the Department of Trade and Industry. The committee's report was kept secret even to the Parliamentary Select Committee on Science and Technology. According to Patterson (1985, 104), the secrecy was dictated by the desire to avoid embarrassment caused by the inability of the committee to decide on the reactor choice. Instead, the committee apparently took up another similarly problematic issue - "the need to streamline Britain's reactor-building industry, and slim it down to match the economically plausible demand on it." [Nuclear Power: Vinter Report: Select Committee Acts. Nature 241(5389): 357]. See also an article (Kenward 1973) in the New Scientist, which argued the Vinter report should have been made public.

<sup>31</sup> A UK House of Lords committee charged with the task of examining providing advice to the government on issues related to EC.

### 4.3 RCEP's 6th report – the “Flowers Report” (1970s)

The sixth report of the Royal Commission on Environmental Pollution (RCEP) – “an independent standing body established in 1970 to advise the Queen, government, Parliament and the public on environmental issues”<sup>32</sup> – was to mark a milestone in British, and to a certain extent international, fast reactor development. The report, published in 1976 and entitled *Nuclear Power and the Environment*, was allegedly the first official statement critical towards fast breeders, and was to be used by opponents of fast breeder reactors also in France (see e.g. Martin 1976) to support their arguments. Patterson (1985, 42) notes that the report laid out its view “in lucid but magisterial terms...with supporting arguments of impeccable authority.” The report generated considerable attention in the media and the nuclear establishment, notably because the chairman of the RCEP heading the commission, Sir Brian Flowers, was himself an ‘insider’ of the nuclear establishment. As a distinguished nuclear physicist, rector of the Imperial College, and a part-time board member of the AEA, Flowers’ views could not be simply dismissed by reference to any “subversive motives” that the nuclear advocates habitually imputed to the “less eminent among their critics” (Patterson 1985, 79). According to Patterson (1985, 42), the report’s “most controversial findings challenged official British policy about plutonium, reprocessing and the fast breeder.”

The Flowers report could be described as one that cautiously endorsed nuclear energy in general, but raised concerns about numerous fundamental issues concerning the way in which nuclear power was being developed in the UK. Already in 1975, Flowers wrote to Prime Minister James Callaghan asking him to delay decisions “on whether to proceed with such a [fast breeder] plant in collaboration with other European countries” until the Royal Commission had published its report. Kenward (1976a) summarises the main highlights of the report, noting that it

- raised concerns about the ‘plutonium economy’, notably the possibilities of “threat and blackmail against society” that plutonium seemed to offer; highlighted the risks of the “construction of a crude nuclear weapon by an illicit group”, as well as the problems associated with producing plutonium in large quantities “in conditions of increasing world unrest”;
- called into question – on environmental grounds – the scale of the proposed nuclear programme, and argued that while commitment to fission power should not be abandoned, “we should postpone commitment to fission and plutonium economy as long as possible”;<sup>33</sup>
- was apparently the first official statement in the UK highlighting the unresolved nuclear waste problem: as it argued that commitment to any significant nuclear fission programme should be contingent on the demonstration “beyond reasonable doubt” that the waste problem can be solved;

<sup>32</sup> Within this remit the Commission has freedom to consider and advise on any matter it chooses; the government may also request consideration of particular topics (<http://web.archive.org/web/20000306220337/www.rcep.org.uk/about.html>).

<sup>33</sup> By contrast, the report was favourable to nuclear fusion, calling for increasing support for the development of “other energy sources”, such as energy conservation, combined heat and power, and fusion (e.g. Kenward 1976a).



- called for support to alternatives sources of energy, including energy conservation, combined heat and power and nuclear fusion; and
- postulated that any major commitment to a nuclear programme, including the construction of fast breeder reactors, should be preceded by a process of public consultation.

The Commission's recommendations on the fast breeders left room for some speculation. On the one hand, it stated that "purely on environmental grounds", the plans to build a commercial fast breeder reactor should be delayed (paragraphs 517-18). On the other hand, it stated that "[w]e don't oppose the construction of CFR1 on environmental grounds", but demanded that the Commission's views be taken into account when government makes decisions on the future of the fast breeder programme (recommendation 49). The ambiguity is perhaps explained by the fact that the Commission was critical about a large-scale fast breeder programme, which it saw as a logical likely outcome of the construction of a CFR1. Hence, the report feared that "the cost and the momentum" of the construction of a CFR would inevitably lead to a large FBR programme in the future, and stressed that there were substantial environmental arguments against a nuclear programme of the scale envisaged in official projections (Nuclear power and the environment 1976; Kenward 1976a). Unsurprisingly, the anti-nuclear NGOs, both in the UK and in France, eagerly seized upon the Flowers report to support their claims about the inherent risks involved in fast breeder technology (e.g. Martin 1976).

In view of this ambiguity, it was by no means surprising that the report would generate heated debate and conflicting interpretations also among the insiders within the nuclear establishment. Walter Marshall, at this time deputy chairman of the AEA and chief scientists for the Department of Energy, criticised the report for ambiguity, underlining that while especially its recommendation no. 49 (stating that there were "no environmental reasons against FBR"), could be read as an endorsement of the FBR programme, the comments by RCEP members after the release of the report highlighted that on purely environmental grounds, CFPR should be postponed.

John Hill, then in charge of the AEA, flatly opposed Flowers' recommendations, referring to the "very clean bill of health to the British nuclear industry", arguing further that Flower report's predictions about the future risks were based on a shaky ground: in the next 25 years the technology would advance greatly, making it simply "wrong" to worry about a large-scale nuclear programme based on technology of the mid-1970s, because this was simply "not going to happen" (Kenward 1976a).

Kenward (1976a) further describes the varying reactions to the Flowers report. Ned Franklin, chairman of the Nuclear Power Company, described the report as reasonable, even though he did not agree on every detail. Con Allday, the chairman of the BNFL, was critical, while some of the senior research staff at his organisation were far less unhappy with the report.

One of the most crucial bases upon which the Flowers commission built its scepticism concerned what it considered as highly unrealistic electricity demand forecasts. The economic stagnation caused by the first oil crisis had brought an abrupt end to the development of the UK electricity supply system, and the rate of growth in electricity



demand fell sharply – in the UK from an average of 7% per year in 1955–1970 to around 1–2% by the mid-1980s (Cheshire 1996, 27). In fact, the use of electricity in Britain fell in the couple of years immediately following the first oil crisis of 1973 (Patterson 1985, 42).

The main changes in government policy triggered by the Flowers report were the transfer of nuclear waste management from the remit of the Department of Energy to the Department of the Environment, the setting up of an advisory committee on the interaction between energy and environmental policy, and the promise, by the environment secretary, Peter Short, that “some sort of public debate” would probably be organised, possibly a planning inquiry commission, before the government decides on the proposed commercial fast breeder reactor (CFR1).<sup>34</sup>

Even though the Flowers Report put a damper over the possibility of building a large commercial FBR, the AEA continued to develop the design for a 1300 MWe demonstration FBR (Parker and Surrey 1995, 835).

#### 4.4 Reprocessing, proliferation concerns and the Windscale Inquiry (late 1970s)

From the beginning of fast breeder development, reprocessing of spent nuclear fuel had constituted an essential element in the vision of a nuclear future based on large-scale exploitation of the technology. Reprocessing was first introduced in the 1940s to provide plutonium for nuclear weapons. In the UK, an integrated plutonium production site, involving both reactors and reprocessing, was established in Windscale, and later run by British Nuclear Fuels (BNFL). The spent fuels from the British Magnox reactors required reprocessing, as a means of preventing the fuel from becoming a hazard<sup>35</sup> (Walker 2000, 835). Even though this necessity disappeared with the adoption of AGR and PWR technologies, reprocessing went on, in anticipation of the emerging “plutonium economy”, in which fast breeder reactors would require a steady supply of plutonium from reprocessing.

In early 1977, all eyes of the nuclear community were at the planned, highly controversial, inquiry into the construction of a reprocessing plant, THORP (Thermal Oxide Reprocessing Plant), at Windscale. Walker (1999, 9-13) describes the main reasons for the BNFL’s eagerness to construct a dedicated reprocessing plant: UK’s desire to become a major player in international reprocessing business, with contracts already signed with European and Japanese utilities in the expectation that a new plant would be built; the BNFL’s favourable bargaining position vis-à-vis the UK utilities (notably CEGB) as a provider of reprocessing services<sup>36</sup>; and need to comply with the Euratom safeguards (the UK had accessed to the Euratom Treaty in 1972). Walker

<sup>34</sup> Government responds to Flowers report. *New Scientist*, 2 June 1977, p. 515.

<sup>35</sup> The reason for this procedure was that spent fuel was temporarily stored in water-filled ‘ponds’, but Magnox fuel’s metallic casing corroded in water. This would no longer be the case for AGR and PWR technologies, because fuel from these plants did not erode in water, and therefore opened the possibility of long-term storage. (Walker 2000)

<sup>36</sup> The UK electricity suppliers could have resorted to long-term storage of spent AGR fuel as an alternative to reprocessing, but they had failed to build enough on-site storage capacity and were therefore highly dependent on BNFL for reprocessing (Walker 1999, 10-11).

(2000) notes that for the BNFL, reprocessing promised to be a highly lucrative activity. Since Germany and Japan had no involvement with nuclear weaponry, they also lacked experience of large-scale reprocessing. Britain and France hence saw their opportunity in providing reprocessing services to these countries. Presumably a key reason for the German and Japanese interest in reprocessing was these countries' desire to avoid the difficult decisions on what to do with their spent nuclear fuel. For the BNFL, reprocessing German and Japanese spent nuclear fuel was all the more attractive, since the customers paid for the service upfront.

A central reason for the calling of a public inquiry on THORP was the series of incidents and radiation leaks between 1973 and 1976, starting with problems with a fuel pond and culminating with the leaks of radioactivity to the Irish Sea (Walker 1999, 13). The decision was precipitated by factors concerning the general contexts, including the forecasts of an increasing role to be attributed to nuclear power and plutonium in energy supply in wake of the first oil crisis, the greater weight that the process of public inquiry was acquiring in numerous areas of governmental decision-making, the rising professionalism of environmental NGOs (e.g. the Friends of the Earth), and the scepticism of the Minister for Technology Tony Benn (formally responsible for nuclear policy) towards the construction of THORP (Walker 1999, 14).

Recognising the high political sensitivities, both nationally and abroad, associated with the possibility of constructing a reprocessing plant designed to treat both domestic and imported spent nuclear fuel, the government held the Windscale Inquiry on the planned reprocessing plant (THORP) and promised to give Parliament a greater say on the decisions.

#### **4.4.1 The institution of public inquiry and the run-up to Windscale Inquiry**

In the UK, a public inquiry is an official review of events or actions ordered by a government body. Unlike a Royal Commission, a public inquiry accepts evidence and conducts its hearings in a more public forum and focuses on a more specific occurrence. In this way, the process enables interested parties to come together, present their arguments and evidence, and examine a specific development proposal in detail (Rough 2011, 24). Each inquiry is a temporary structure, and can last anywhere between one day and several years. Inquiries have been a habitual feature of the regulatory framework governing the siting of power stations for more than a century. An inquiry was mandatory in case the local planning authority objected to the granting of an approval for the project in question. Otherwise, inquiries are held at the minister's discretion. Subsequent to the decision to hold an inquiry, the minister appoints an inspector to oversee the proceedings. At the completion of the process, the inspector submits a report summarizing the cases for and against the proposal, and provides specific recommendations concerning the granting or withholding of consent. While the minister usually takes the final decision, based on considerations of 'national interest', the inspector has considerable discretion over the format of the inquiry. For instance, Rough (2011, 30) notes that the nuclear inquiries in the period 1955-1961 allowed discussion not only on the local-level project in question, but also on the broader aspects of the country's nuclear policy.

Walker (1999) cites three functions provided by public inquiry: a means for openly venting conflicts and disagreements in a quasi-judicial arena; a means of arriving at definite decisions through a rational procedure examining the virtues and the downsides of a given proposal; and an opportunity for politicians and authorities to legitimise their decisions. Public inquiries are non-judicial ‘advisory mechanisms’ that form a part of “the fabric of administrative jurisdiction” in Britain (Wraith and Lamb 1971, 31). In theory, they are intended to provide information to assist the minister in the implementation of a pre-existing policy, but in practice they serve a more strategic, political function (Rough 2011, 24). Such functions include that of a “safety valve” allowing opponents of a contentious development to “blow off steam” (Drapkin 1974, 243), and the legitimisation of controversial decisions and policies (Kemp 1985). Public inquiries have served a crucial function also in decisions concerning nuclear power in the UK, representing for instance in the late 1950s and early 1960s “the only formal opportunity open to the public to question the siting of a nuclear facility”. Wynne (1982, in Rough 2011, 24) notes that the seven public inquiries held on nuclear reactors between 1956 and 1961 “were a rare point of contact between the public, national groups, such as the Council for the Protection of Rural England, policy makers, and industry”.

While the British planning law required only that the local Cumbria County Council approve the BNFL planning application for a reprocessing plant at Windscale, by mid-1976 the plan had aroused wide-ranging debate and opposition. The Energy minister had deemed the outcome of the two public debates, held in 1975 and 1976,<sup>37</sup> sufficiently positive to warrant a continuation of “overseas business” by BNFL. On 25 June, 1976, BNFL then submitted a formal application to the Cumbria County Council for an outline planning application. The Council was indeed minded to accept BNFL’s application, but decided nevertheless to refer the issue to the Secretary of State for the Environment, Peter Shore (Greenhalgh 1978). Despite the government’s initial reluctance (for details, see Walker 1999, 13-14), the Secretary of State for the Environment, Peter Shore, announced in the end of 1976 that the Windscale proposal would be made the subject of a planning inquiry. The final trigger for the inquiry was the “sensational publicity” (Greenhalgh 1978) following the revelation, in December 1976, that the BNFL had failed to inform the government about a leakage of low level radioactive water from a storage silo containing spent fuel hulls (Greenhalgh 1978; Walker 1999, 14). Unlike the previous public inquiries concerning nuclear installations, which had been rather routine procedures focusing on local issues (Walker 1999, 13), the Windscale Inquiry would consider also national and international aspects of the proposal. The Inspector in charge of the Inquiry would report to the Secretary of State for the Environment, who with his Cabinet colleagues would then take responsibility for approval or rejection of the BNFL application. Exceptionally, Parliament was entrusted with the decision on THORP through the device of a Special Development Order upon which the House of Commons would vote (Walker 2000, 837).

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<sup>37</sup> A public debate was first held on 11 December 1975 at local level at Barrow in Furness and then on 15 January 1976 at the national level at Church House, Westminster, on the proposals to refurbish the existing Magnox reprocessing plant, and to build the THORP plant. The debates were held under presumably independent chairmen, with participants including environmentalist groups and a wide range of representatives of local and national organisations. (Greenhalgh 1978).

The inquiry was led by Justice Parker, assisted by two technical assessors – Sir Frederick Warner, a chemical engineer of international repute, and Sir Edward Pochin, a radiologist of similar eminence (Patterson 1978), and the various witnesses gave their evidence under oath (Greenhalgh 1978). According to Walker (1999, 36), the quality of the inquiry suffered from the fact that especially Warner was known as a staunch advocate of fast breeder technology, and had presumably a strong influence on judgements made by Parker. Indeed, a number of environmental NGOs, together with the government of the Isle of Man, immediately protested against the composition of the commission (Patterson 1978). The designation of a judge of the High Court<sup>38</sup> rather than just a Department of the Environment official to lead the inquiry testified to the exceptional nature of the Windscale Inquiry (Patterson 1978), and to the desire to ensure the independence of the procedure.

#### 4.4.2 Reprocessing, FBRs and proliferation fears

For the development of FBRs, the question of reprocessing was crucial, as the key underlying rationale for reprocessing was the utilisation of reprocessed fuel in fast breeder reactors. Furthermore, Collingridge (1984b, 62) argued that the choice of the AGR technology and reprocessing its waste in the THORP reprocessing plant played in favour of fast breeders. The construction of THORP would increase the attractiveness of an FBR as an investment, since learning how to reprocess thermal oxide fuel, such as that from AGRs, was seen as an essential step towards a breeder economy. In financial and economic terms, the choice of AGR had provoked equally significant: without the AGR, there would be no immediate need to invest in THORP, and the costs of THORP would appear on the balance sheet of the breeder, whereas with AGR, the cost of THORP would appear on that reactor's account.

The lead-up to the Windscale Inquiry risked being difficult for the fast breeder advocates, since only a month before the opening of the inquiry, in May 1977, an explosion took place at the PFR at Dounreay, in the access shaft leading into a waste-disposal tunnel under the seabed offshore. However, Patterson (2010, 81-82) holds it as hardly a surprise that almost no mention was made in the media about the explosion. Just a month earlier, on 7 April 1977, the Carter administration in the US had added to the difficulties, by its decision that the country would give up the development of reprocessing and fast breeders, mainly because it deemed the associated proliferation risks as excessive.

European and Japanese governments were not discouraged by the US government's decision to give up reprocessing, but sought instead to set up infrastructure needed to make the 'plutonium economy' a reality. The American non-proliferation policy did not seem to have a great impact on UK decisions; indeed, a former AEA scientist described the Americans' concern for proliferation as somewhat excessive 'hysteria'. However, as mentioned by our interviewees, proliferation was very much on the

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<sup>38</sup> The High Court deals at first instance with all high value civil disputes, and includes also the administrative court, with a broad range of cases under its responsibility (<http://www.justice.gov.uk/guidance/courts-and-tribunals/courts/rcj/index.htm>).

agenda of public discussion and NGO opposition against the ‘nuclear complex’. Even industry insiders voiced concerns in the late 1970s, with the Flowers report as a prominent example. The Independent newspaper (Buchan 1993) quotes a presumably famous lecture given by Lord Marshall, the head of the CEBG in the 1980s, at Salford University in 1979: *“There is . . . a risk that if plutonium-bearing thermal reactor fuel is developed and used in any thermal reactors, it will ultimately be used the world over. This may give rise to a significant increase in the technical opportunities for proliferation (of nuclear weapons) with only a marginal economic and resource gain to set against the risk.”* Proliferation risks were likewise evoked by Papadopoulos (1981), who reminded of the dangers involved in plutonium transport that a plutonium economy based on fast breeders and reprocessing would require. The technical and administrative measures proposed by the nuclear industry to prevent such threats would, according to Papadopoulos, not only impose significant costs, but would also potentially threaten civil liberties.

#### **4.4.3 The outcome of the Inquiry: landmark of participatory decision-making or a symbol of opposition against the ‘nuclear complex’?**

The Windscale Inquiry began its hearing on 14 June 1977 and ended on 4 November 1977 (Greenhalgh 1978). The main participants in the inquiry were represented by a legal counsel. The 100 days of inquiry involved oral evidence and cross-examination from several dozen witnesses, and all the sessions were open to the press and the public (Patterson 1978). The Inquiry transcript totalled over 4 million words, backed by some 1,500 documents (ibid.). As evidence for the neutrality and balanced approach of the inquiry, Greenhalgh (1978) evokes the numbers of days spent on hearing different parties to the debate: “BNFL occupied 30 of the 100 days, BNFL supporters another 10 days, Government departments 10 days, the objectors 40 days, with 10 days given to opening and closing statements.” According to Greenhalgh, BNFL produced 17 witnesses and received support from another 19 organisations and individuals, while the objectors produced as many as 84 witnesses including a number from the United States. The cost of the Inquiry was well over £1 million (Patterson). To the surprise and dismay of the project’s opponents, the final report of the inquiry, published in January 1978, declared unequivocal support to the immediate construction of THORP, as the BNFL had requested. Exceptionally, Parliament was entrusted with the final decision on THORP through the device of a Special Development Order upon which the House of Commons would vote (Walker 2000, 837).

The inquiry has been hailed as a ‘landmark in British nuclear policy making’ (Hall 1986, 161), thanks to its broad scope and participatory approach (Shore 1977, cited in McAuslan 1979, 15). Greenhalgh (1978) evokes the suggestion by the Secretary of State for the Environment that no other country in the western world had ever had a more open, thorough and impartial examination of a major nuclear proposal, as well as the final submission by Mr. Kidwell, the Counsel for the Friends of the Earth, recognising the impartiality of the Tribunal.

However, a substantial number of observers have argued to the contrary, criticising the final report and the inquiry process on a several counts. Patterson (1985, 126)



argued that the report had failed to justify why the arguments of the opposition had been rejected. In an interview for support of this report, Patterson explained his disappointment as the lead witness of the Friends of the Earth: “along with another colleague and a very experienced lawyer we came away from the inquiry absolutely convinced we had made an unanswerable case against them acquiring permission for building the plant. But the inspector of inquiry ignored our case and gave the full go ahead to BNFL to build the plant.” Patterson (1978) further evoked “the Inspector’s persistent misrepresentation of witnesses, by selective quotation out of context.” The opponents were dissatisfied with the way in which the report makes many witnesses to appear as if they were “advancing arguments diametrically opposite to their actual presentation before the Inquiry” (ibid.). Greenhalgh (1978) refutes this charge by arguing that it was based on a misunderstanding of the nature and the function of an inquiry, which was not to provide “a summary or precis of the differing views put forward at the Inquiry” but instead to present “the basis on which the Inspector’s view was formed”, including the arguments and evidence underpinning the judgment. Walker (1999, 15-22) highlights what he saw as the three main shortcomings in the inquiry: the Inspector’s predisposition to approve BNFL’s proposal, which lead to an inadequate framing of the question; misrepresentation of uncertainty as if the only uncertainty concerned future demand of energy, and giving greater credence to high rather than low forecasts of energy demand; and the failure to consider the ‘exit options’, i.e. the ease or difficulty with which the UK could escape – or at least modify – the plan to construct the plant in case the future was to turn out different than predicted.

Wynne (1982), in his seminal work on the Windscale Inquiry, takes a broader view and condemns the inquiry process as erroneous; he contends that the entire inquiry process was built on methods of analysis and interpretation, which reflect symbolic universes that contain their own implicit morality and social meaning. According to Wynne, big inquiries such as that on Windscale are not intended to dig below the surface of a particular rationality and ritual. Patterson (1978) notes that the “objectors were by no means the only ones unimpressed by the Report”, evoking critical editorials in *The New Scientist*, *Nature*, and the *London Observer* that questioned the Report’s conclusions and counselled caution, and other newspapers and magazines including the *Times* and the *Economist* that “found the Report’s discussion of the proliferation case unconvincing”. Finally, it is notable that the criticism against the Windscale Inquiry seems to have persisted for a long time. For example, Buchan (1993) reports about a senior government official of the Conservative government of John Major, sceptical about THORP, who clearly did not hold the Windscale Inquiry and the recommendations by Mr Justice Parker from fifteen years earlier in much esteem: “You don’t want to build anything on Parker”.

Indeed, reprocessing has been a significantly more contentious issue in the UK nuclear policy than that of FBRs, largely because of the alleged very high economic cost of running THORP, the widespread view according to which the Windscale Inquiry (on the construction of THORP) was highly defective and one-sided, and the intimate link of reprocessing with the problems of finding a solution to the nuclear waste problem (e.g. Buchan 1993). One of our interviewees, who was among the leading figures at the Friends of the Earth at the time, argued that THORP had “left a huge radioactive elephant at stupefying cost to UK taxpayers”. Moreover, the



Windscale Inquiry represented a landmark case in the UK nuclear policy, and in UK planning and decision-making more generally (e.g. Walker 1999). Furthermore, the Inquiry became an important symbol for the anti-nuclear movement, despite its failure to prevent the construction of THORP (Walker 1999, 28).

Unsurprisingly, in view of the intense political confrontation that Carter administration's decision had triggered between the US and the rest of the world - or at least between the nuclear establishments in these countries – the Windscale Inquiry and the parliamentary debates following it were strongly marked by proliferation concerns (e.g. Walker 1999, 22-27; Walker 2000). As a result of the high-level diplomatic exchange that had followed Carter administration's declaration, a study called the International Nuclear Fuel Cycle Evaluation (INFCE) was launched in October 1977, with participation from 66 countries and five international agencies. Patterson (1985, 116) argues that while the INFCE was supposedly only technical in nature, with the task of comparing different nuclear fuel cycles and their possible use for acquisition of weapons, in reality its outcome was to a large extent the result of intense lobbying from the "plutonium lobbies" of countries such as the UK (with the AEA at the forefront) in favour of reprocessing and the fast breeder. The report therefore declared that proliferation was a political problem, which should be left to the politicians to solve (Skjöldebrand 1980).

#### 4.5 CFR – an experimental or commercial reactor? (late 1970s)

With the Windscale Inquiry still underway, in September 1977, the Select Committee on Science and Technology published the report 'Alternative Sources of Energy' recommending the construction of a commercial fast breeder reactor (CFR). However, by this time, the government had become increasingly hesitant to proceed with the CFR as its main concern was to ensure the nuclear manufacturing sector in the UK would stay afloat, by placing an order on thermal reactors that could be brought on line with a minimum delay. In a similar way as in France, the 'fast breeder dream' was giving way to the need to ensure the quick construction of thermal reactors, which in the UK also meant choosing between alternative designs - between the AGR and the PWR.

Not only the gradual shift in the status of the fast breeder from the flagship project of nuclear industry to a long-term R&D project, but also the confusion and disagreement around the late 1970s about the name of the planned new reactor were reminiscent of the French fast breeder development. The question was obviously not only semantic, but would have profound implications on who was to pay for the new reactor.

In 1977, John Hill (AEA) declared that the proposed new reactor would not be experimental, but just another nuclear power station, of a new design. However, as pointed out by Patterson (1985, 84), if this were the case, the 'commercial' reactor would not be paid by the AEA, but by the CEGB, the electricity supplier. However, according to Patterson (2010, 84), the CEGB was prepared to provide a site for the new fast breeder, but did not want to invest in the plant, not least because it was already struggling with excess generating capacity and did not want to get involved in the construction of yet another potentially problematic plant. The AEA therefore

quickly proceeded to changing the denomination of the new reactor, with Sir Hill this time declaring that "the plant would not be in any conventional sense 'commercial'. It would 'demonstrate' the design for a commercial plant; but its electricity output would not be competitive in cost with that from conventional generating plants" (Patterson 1985, 113). Observers were quick to point out the inherent contradiction in the new name of the reactor - the Commercial Demonstration Fast Reactor (CDFR): surely, a reactor would have to be either commercial or for demonstration – not the two at the same time (Sweet 1982, 26; Patterson 2010, 84).

In addition to the question of the sharing of the financing burden, the name of the reactor would affect the criteria against which the performance of the reactor would be assessed. A commercial reactor could only be judged as a success if it was economically viable, whereas an experimental reactor would be judged largely on its technical performance, notably its ability to provide a solid basis for the subsequent deployment of commercial reactors. Sweet (1982, 26) argued that as a de facto experimental reactor, the new CDFR should be evaluated in light of the opportunity costs of public R&D: "CDFR "should more properly be regarded as another stage in fast reactor R&D", and the opportunity costs involved therefore ought to be quantified.

These semantic battles were symptomatic of an atmosphere that had become increasingly hostile to the rapid introduction of a commercial-scale fast breeder reactor. Therefore, the approval given by the Energy Secretary Tony Benn in January 1978 for the construction of a new PWR pushed the introduction of a commercial fast breeder further into the future, in the context of a stagnant electricity demand and the existence of excess generating capacity. In the same year, the government decided to hold off constructing a commercial FBR until a full public inquiry, similar to the one just organised on the construction of THORP, would be conducted. Concerns about the need to ensure adequate public participation in decision-making gained more importance during this period, with the AEA producing its first publicly available cost estimates on the construction of a commercial fast breeder reactor (e.g. Pearson 1978). The on-going debate on "coal vs. nuclear" was to large extent framed in terms of costs – an approach criticised for instance by Pearson (1978, 78), who remarked that "[m]ore relevant than coal versus nuclear economics is the effect of fast breeder development on the UK economy and employment prospects."

#### **4.6 "Thatcher the scientist" takes office: an interlude of optimism in the fast reactor community (late 1970s)**

The election of Margaret Thatcher as the Prime minister in May 1979 briefly revived the hopes of the fast breeder advocates. Thanks to her scientific training, Thatcher had a capacity exceptional for a politician to understand the technical intricacies involved in nuclear power. Moreover, soon after taking office, on 6 September 1979, she visited Dounreay, and openly declared the government's support for the fast breeder project, pending on an inquiry:

*"My own personal view is that we should continue with fast reactors, but the government has agreed and is therefore obliged to have an inquiry, and it is not up to me to prejudge the outcome." (Patterson 1985, 116)*

The revival of the support to fast breeders turned out to be short-lived, as the attention soon shifted again to the thermal reactor programme. For example, in 1981-82, the main focus of nuclear controversy was about the PWR Sizewell B, while “the fast breeder people kept their heads down” (Patterson 2010, 85).

#### **4.7 International collaboration - preparations for the 'fallback option' begin (late 1970s to 1980s)**

Despite the initial optimism that Thatcher's open endorsement of nuclear power and fast breeders had generated, fast breeder people were already in the late 1970s preparing for international collaboration as a fallback option if and when the national FBR programme would not advance as expected.<sup>39</sup> As Judd and Ainsworth (1998, 615) note, as the prospects for commercial exploitation of fast breeder technology was pushed further into the future and the emphasis progressively shifted to R&D, separate national programmes appeared increasingly wasteful and expensive. As argued by Patterson (1985, 117), this was not to be simple and easy either. By this time, the British government had to concede that the French were now leading the Western world in fast breeder development. While the French Phenix plant at Marcoule had had its troubles, it was nevertheless operating and generating electricity much more reliably than the Dounreay PFR. Likewise, the full-scale Superphénix at Creys-Malville was behind schedule and over budget, but expected to be on stream by 1984. Concretely, the French dominance meant that they were able to impose on the British an 'admission fee' of £50 million if they wished to participate in European fast-breeder collaboration (Patterson 1985, 117).

Patterson (1985, 114) describes the dilemmas faced by CEGB concerning European collaboration. The plans for European collaboration involved the construction of three separate full-scale demonstration plants in France, Germany and Britain. The CEGB had already in the 1970s agreed to take a 3 % interest in the international group, SBK (Schnell-Bruter-Kernkraftwerk), which owned 16 % of the French Superphénix 1200 MW plant which was under construction, and was planning a sister station, SNR-2, in Germany. The minuscule holding hardly allowed the CEGB to actively participate in the development, but enabled it to keep an eye on the continental fast breeder activities.

Furthermore, despite the proliferation anxieties in the US, the Americans and the British set up a joint research group, using Dounreay and the nuclear power facilities in Idaho Falls as examples. The UK was also working on establishing a research group, Fastec (fast reactor technology) to exchange experience and data with Serena, a company comprising its European counterparts including France, Germany, Belgian, Italy and the Netherlands.

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<sup>39</sup> For example, one of our academic interviewees (economist), noted that European collaboration provided an 'exit strategy' for national fast breeder programmes, but questioned whether a project that was not economically viable at the national level could be rendered viable simply by pooling resources at international level. See also Patterson (1986).

Collaboration started in 1982 between France, Germany, Belgium, the Netherlands and Italy, and in January 1984 Peter Walker, Secretary of State for Energy, and Sir Peter Hirsch, the chairman of the AEA, signed an inter-governmental memorandum of understanding which opened the way for wide-ranging cooperation and eventually to the merging of the UK fast reactor development programme with those of its continental neighbours (Judd and Ainsworth 1998, 615). The cooperation involved electricity suppliers, as well as nuclear and fuel cycle organisations in each country – from the UK, the CEGB, the AEA, British Nuclear Fuels and the National Nuclear Corporation.

## V. THE FINAL COUP DE GRACE: CHANGING EXTERNAL ENVIRONMENT, THATCHER'S POLITICAL AMBITIONS AND ECONOMIC LIBERALISM (1980S)

The rhetoric in favour of fast breeders remained strong in the late 1970s and even early onto the 1980s. Patterson (1985, 114) argues that the nuclear energy proponents continued to support the FBR with 'evangelical fervour'. Some AEA staff continued until at least 1977 talking about a vast and immediate programme of fast breeders. The technology was still portrayed as a means to meet the world's increasing future energy needs. The government also kept to its rhetoric in favour of the fast breeder programme. Following the government's review of the fast breeder programme in November 1982, during the Sizewell inquiry, the Secretary of State for Energy, Nigel Lawson, addressed his view to the House of Commons (Patterson 1985, 117-118):

*"The Fast Reactor is of major strategic significance for the UK's and the world's future energy supplies. It is 50 times as efficient a user of uranium as thermal reactors such as the Advanced Gas-cooled Reactor and Pressurized Water Reactor, and can create out of the spent fuel and depleted uranium which has so far arisen from our thermal programme fuel equivalent to our economically recoverable coal-reserves.*

*The UK is among the world's leaders in the development of this technology. Through the successful programme of research and development undertaken by the Atomic Energy Authority, which centres on the operation of the Prototype Fast Reactor and associated fuel cycle at Dounreay, we have demonstrated the feasibility and potential of this technology. We have also collaborated with other major countries who have programmes in this field. We are in an excellent position to carry the programme forward and to prepare for the introduction of commercial fast reactors when these are needed to augment our thermal reactor programme.*

*The Government has therefore decided to continue with a substantial development programme for the fast reactor based on Dounreay and I have asked the Chairman of the Atomic Energy Authority, Sir Peter Hirsch, in consultation with the generating boards, British Nuclear Fuels Ltd and the National Nuclear Corporation to draw up a future development programme which makes the best use of our resources and*

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*experience.*

However, Lawson's on the surface positive statement about fast breeders as a technology of key strategic importance tended to conceal a subtle message about fast breeders as a technology for the future, which will eventually be needed as a supplement to the thermal reactor programme. Lawson further noted that "the series ordering phase will begin in the earlier part of the next century" and that the development programme would "be geared to this timescale" (Patterson 2010, 85).

In essence, this declaration meant that the government was slowing down the programme, and the AEA cut its R&D expenditure on fast breeders by a third, to about £70 million a year (Campbell 1984). The shift in emphasis away from fast breeder R&D to the construction of thermal reactors also further marginalised the AEA in the UK nuclear community, and the concomitant rise in the status of the CEGB. According to one of our AEA interviewees, such a shift, in turn, contributed to a 'brain drain' as capable AEA scientists and engineers – especially those who wished to 'make a difference' – sought work opportunities at the CEGB.

Kreczko et al. (1987, 303-304) report on a lecture delivered to the British Nuclear Energy Society on 15 September 1983<sup>40</sup> by Sir Peter Hirsch, the former Chairman of the AEA. Hirsch expressed the official view that a demonstration fast reactor (CDFR) should be in operation by the year 2000, based on the assumption that the Generating Boards should decide on the first series-orders at around 2005, with the entry in operation of these reactors in 2015.

At this point in time, the timetable for the introduction of commercial fast breeder reactors had slipped far to the 21<sup>st</sup> century, in stark contrast with the optimism that had prevailed until the early 1970s. This postponement was brought about largely by the changes that had made the external environment much more hostile to nuclear energy in general and to fast breeders in particular. The changes were summarised by Piran (1984, 180-181) through the following sequence of events:

- economic stagnation in the Western economies and the Three Mile Island accident, which led to...
- a sharp drop in the number of orders for new nuclear stations, which in turn...
- undermined earlier estimations of growth in nuclear industry and the evolution of uranium prices, which again were accompanied by...
- the escalation of the cost of reprocessing and...
- difficulties in gaining public acceptance.

Piran (1984, 181) concluded that the large-scale deployment of fast breeders would therefore almost certainly be delayed.

Apart from the Three Mile Island accident, public opposition against nuclear energy was further fuelled by growing concern about radiation safety and probably by the massive demonstrations in France against the Superphénix project in Creys-Malville in 1977 (despite the fact that the opposition in France waned after this traumatic

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<sup>40</sup> Published in *Atom*, No 325, November 1983, pp 242-251.



demonstration, in which one demonstrator died). The potential negative health effects of the Dounreay site gained increasing attention as a particle of irradiated Material Testing Reactor (MTR) fuel was found in 1983, in a routine radiological survey at predetermined locations on the Dounreay beach (Toole 2005). The particle was primarily composed of aluminium and contained a small amount of uranium as well as fission products (*ibid.*). The discovery resulted in the closure of beaches along a 10-mile coastal stretch, and warnings against swimming in the sea<sup>41</sup>, and the BNFL was fined £10,000 for the discharge.<sup>42</sup> The ‘beach incident’ was closely followed by a Yorkshire TV documentary “Sellafield – the nuclear laundry”, which alleged there was a cluster of leukaemia cases linked to the site (Osborne and Huston 2009). Even though no causal link between Sellafield and leukaemia clusters could be established, the wide media coverage was to tarnish Sellafield’s reputation for years. The beach incident contributed to the launching of regular monitoring of radioactivity on Dounreay beaches (Toole 2005). It also prompted the BNFL to revise its PR strategy. The company sought to remedy the reputation of dishonesty and secrecy that prevailed among citizens, by demystifying Sellafield through an ‘open door’ policy, newspaper advertisement campaign, organised media visits to Sellafield, and the construction of a Visitors Centre (Osborne and Huston 2009). Moreover, the leaks in Windscale, which had ultimately triggered the public inquiry on THORP, had further eroded public confidence in the technology.

While Judd and Ainsworth (1998, 615) recognise the importance of the technical problems and the high cost of the PFR as contributory factors to the postponement and eventual cancellation of the CFR project, they attribute the main cause to the revisions in the electricity demand and uranium price forecasts, i.e. what the developers and advocates of fast breeders often conceive of as ‘external factors’. Judd and Ainsworth likewise note that the utilities were fully occupied in getting thermal reactors up and running.

The above factors were valid across the entire Western world, yet a decisive factor in the UK was the increasing importance of economic assessment in decisions on energy policy. The change was felt particularly hard at the AEA, which had until 1971 enjoyed a nearly full freedom to develop its ‘curiosity-oriented’ (Gowing, 1974a, 207) research activities unhindered by economic constraints. The organisational changes in 1971 triggered a process whereby economic considerations gained importance, and increasingly limited the scope of the kind of ‘blue skies’ research practiced in the AEA. The entry in power of Thatcher government was a landmark in this development, yet as many of our interviewees underlined, the roots of the ‘economic dogmatism’ that came to characterise British energy policy for the subsequent three decades lie deeper in the evolution of the British society: a long-term adherence to a more economy and efficiency-oriented approach, and the near-abandonment of the objective to create ‘national champions’ through active industrial policy. Spence (1987, 37) follows the same line of argumentation, in noting the profound ideological and historical differences between the UK and France. Formally, the structure of the UK’s nuclear sector was similar to that of France: there was a single reactor

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<sup>41</sup> <http://en.wikipedia.org/wiki/Sellafield>

<sup>42</sup> Hansard, "Written answers for Friday 5th May 2000". Retrieved 16 August 2011. <http://www.publications.parliament.uk/pa/cm199900/cmhansrd/vo000505/text/00505w05.htm>



corporation (the National Nuclear Corporation, NNC), two state-owned utilities (CEGB and South of Scotland Electricity Board, SSEB) dominating power-station ordering, and one state-owned research body (AEA). However, Spence argued that the “state-monopolist tendency does not have deep roots in the UK”, which he portrayed as “the homeland of classic liberal internationalism” (ibid.). Spence considered that the especially the complicated decisions over reactor design in the 1970s were an illustration of the way in which, within the framework of national institutions, battles were being fought, which had been resolved elsewhere 20 years earlier (ibid.).

It is notable that while the changes in the external environment contributed to the termination of the fast breeder programme, they did not halt reprocessing, whose rationale nevertheless greatly depended on the fast breeder programme. Walker (2000) explains such an inertia through the various types of ‘commitments’,<sup>43</sup> which allowed reprocessing to continue even after its underlying rationale – notably the justification for fast breeder reactors – had disappeared – for much the same reasons as those evoked above. By the time that the construction of THORP began in 1984, world energy prices had fallen substantially and few countries ordered new nuclear power stations. The expected rise in uranium prices did not materialise, and the need for plutonium to fuel a continuing expansion of nuclear investment quickly evaporated.

### 5.1 The (poor) economics of nuclear power 'revealed': calls for greater financial accountability (late 1970s to 1980s)

Many observers have explained the decline of nuclear power in the UK by the increasing scrutiny under which the economic costs of the industry were brought over the course of the 1970s and 1980s. Henney (1994, 7) goes as far as arguing that “[f]or a quarter of a century the CEGB, the South of Scotland Electricity Board (SSEB) and the government consistently misled Parliament and the public about the cost of nuclear power”, and talks about the “CEGB's obsession with building expensive nuclear power stations and ever larger coal plants” (Henney 1994, 9). While such an interpretation may be extreme and partly unjustified, it is clear that the atmosphere and the criteria against which the fast breeder was examined had undergone a fundamental revision by the late 1970s. Hence, the late 1970s and early 1980s saw a multiplication of economic analysis of the British nuclear policies both in the academic literature, and by the official institutions. Even more than the question of the ‘real’ costs of fast breeders, this economic debate concerned topics such as the choice between coal and nuclear (e.g. Pearson 1978; Parker and Surrey 1995) and the costs of reprocessing (Piran 1984). As one of the most illustrative portrayals of the government’s new approach to decision-making on energy Parker and Surrey (1995, 821-822) evoke a speech given in 1982 by the then Secretary of State for Energy, Nigel Lawson. In his speech, Lawson argued against the attempts at ‘guessing the unguessable’ and against detailed central planning from Whitehall. By contrast,

<sup>43</sup> Walker (2000, 833) describes such commitments as essentially social in nature, “usually including legal (especially in the form of contracts), organisational (involving producers, users and financiers), and political (involving various actors associated with the state) commitments.”

energy prices would be the best instrument that would send appropriate signals to consumers and producers to encourage efficiency. Competition, private enterprise, and the free play of market forces would be needed to curb the power of state monopolies, while investment decisions would be based on strictly commercial criteria as opposed to security of supply considerations. And yet, this did not prevent Lawson from praising the large French nuclear programme or expressing confidence in the proposed British PWR programme – products of central planning rather than market forces.

One of the most crucial of the economic analyses was conducted by the Comptroller and Auditor General in February 1984. The report “Development of Nuclear Power” examined the economic and financial viability of the fast breeder programme and the AEA’s financial standing, and subsequently led to further investigation by the House of Commons Committee of Public Accounts. Patterson (2010, 87) explains the reasoning that the Parliament Select Committee on Energy expressed in its conclusions on 19 July 1984 concerning the costs of the fast breeder programme. The committee concluded that the total expenditure accorded to fast breeder R&D from 1955 to 1983 amounted to some £2400 million (in 1982-83 money values), and that the annual R&D expenditure had remained remarkably steady at between £85m and £120m in the twenty years since 1962-1963. Assuming the estimates provided by the AEA Chairman (Sir Peter Hirsch) in his evidence to the committee – further 25-30 years and additional R&D expenditure of £1300 million – together with £2 billion construction costs for a commercial demonstration reactor and £300 million for reprocessing facilities, the Committee concluded that the total estimated further expenditure would lie at £3.3 billion and a cumulative figure at £5.7 billion. Hence, the fast reactor would be “roughly halfway through a perceived 60-year research, development and demonstration programme” (Patterson 2010, 87).

Campbell (1984) reported on further criticism brought forth by the Committee: the lack of major specific targets in the UK’s fast breeder development programme, which had presumably weakened financial control; since there was no government commitment to the construction of a commercial fast breeder reactor, and the AEA had specified intermediate milestones neither for the costs nor the achievement of the programme, it was difficult to judge whether the annual spending allocated to the programme by the AEA was justified. Parker and Surrey (1985, 842) note the Committee’s conclusion according to which 82% of the Department of Energy’s R&D expenditure went to nuclear power – disproportionate to the relatively small potential contribution of nuclear power in meeting UK’s primary energy demand – and that nuclear R&D was nevertheless scrutinised far less than the much smaller amount of non-nuclear R&D funded by the Department. Apparently the committee report did not go without provoking changes in the AEA, as demonstrated by comments by one of our interviewees – a former AEA employee – concerning the pervasive changes towards project-based and performance-based management within the AEA, especially since the entry in power of the Thatcher government.

The committee was sceptical, to say the least, about the future of fusion power, arguing that fusion power would not be needed if the fast breeders were developed. If, on the other hand, the FBR were rejected due to the associated radioactive waste

problems, then, logically, fusion would have to be abandoned on the same grounds (HC 585, 1984, paras 28 and 29, in Parker and Surrey 1995).

The Committee was equally critical towards the existing plans for Franco-German-British collaboration on fast breeders, in which each country would develop and build their own demonstration FBRs. This, the committee noted, “would be far more costly than joining efforts to develop and build a single demonstration plant licensable in each of the participating countries (HC 585, 1984, paras 22-24)” (Parker and Surrey 1995, 842). The committee hence found “the proposal difficult to understand, except on political grounds”, wondering what would be the added value of collaboration that would involve each country pursuing roughly the path they had been following independently (Patterson 1985, 121).

In late 1985, while the AEA continued to pursue its FBR programme and was pushing for approval for a European Demonstration Reprocessing Plant for fast breeder fuel at Dounreay, the Thatcher government announced further cuts in the annual funding for fast reactor development (Patterson 2010, 87).

## 5.2 European fast breeder project – the last glimmer of hope (mid-1980s to 1990s)

Despite the doubts expressed in 1984 by the Energy Committee, international collaboration gained an increasingly important position in UK’s fast breeder activity. Therefore, the European Fast Reactor (EFR) programme was initiated in 1985 between the UK, France, Belgium, Italy and Germany, with the UK contributing 20% of the project cost. According to Patterson (1986), the European project was merely a face-saving measure undertaken by national authorities, which had until then invested considerable amounts of money and prestige in fast breeder programmes.<sup>44</sup> The official aim was to design a 1500 MW prototype reactor by 1993 and to generate electricity at a cost around three times less than light water reactors. In early 1986 a public inquiry opened into the proposal to build a fast reactor fuel reprocessing plant at Dounreay as part of the programme (Kreczko et al. 1987, 303). Still in August 1985, Sir Peter Hirsch expected that at least four commercial-size reactors would be in operation in Europe just after the turn of the century: Superphénix 1 and 2 in France, SNR 2 in Germany and CDFR (or UK 1) in the UK (Hirsch and Farmer 1986, 301). Then, on 26 April 1986, came Chernobyl. The accident cast doubts over every form of nuclear activity, triggering public opposition even at Dounreay. Then yet another steam-generator failure forced a six-month shutdown of the PFR (Patterson 2010, 87).

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[http://books.google.fi/books?id=wAYAAAAAMBAJ&pg=PA38&lpg=PA38&dq=caithness+fast+bree+der&source=bl&ots=Wgyuie1CbN&sig=V-IICwqR\\_aP0VYUxIF6Gd8x5xB8&hl=fi&ei=BiRFTsOKNoOhOsmm0OcD&sa=X&oi=book\\_result&ct=result&resnum=5&ved=0CDsQ6AEwBA#v=onepage&q=caithness%20fast%20breeder&f=false](http://books.google.fi/books?id=wAYAAAAAMBAJ&pg=PA38&lpg=PA38&dq=caithness+fast+bree+der&source=bl&ots=Wgyuie1CbN&sig=V-IICwqR_aP0VYUxIF6Gd8x5xB8&hl=fi&ei=BiRFTsOKNoOhOsmm0OcD&sa=X&oi=book_result&ct=result&resnum=5&ved=0CDsQ6AEwBA#v=onepage&q=caithness%20fast%20breeder&f=false)

Even at the end of the 1980s, many fast breeder advocates still retained their belief in the technology, despite the recurrent drawbacks and delays in the development of the fast breeders since the 1970s. For instance, in his comprehensive review of policy and prospects, Professor P.M.S. Jones (1987) maintained that this sort of reactor had “been demonstrated technically” and portrayed “many attractive safety features” (Conway 1989, 64).

In 1988, the main design activities of France, Germany and the UK were merged. A combined organisation called EFR Associates (EFR-A) was set up by Siemens, Novatome and NNC to design a new European Fast Reactor (EFR), incorporating features from the three national projects. The national R&D programmes were merged in support of it. At the same time the main West European utilities in Belgium, France, Germany, Great Britain, and Italy formed the European Fast Reactor Utilities’ Group (EFRUG) which acts as the potential customer for an EFR, which was expected to be built in one or several of the participating countries after 1996-1997, with a view to preparing a series of plants by about 2010 (Crette 1998, 585). Judd and Ainsworth (1998, 615) deemed that the EFR design had by 1994 reached a point where further work would depend on the selection of a site, and estimate that the costs of an EFR would “fall within the range of projected costs of advanced PWR reactors.”

In February 1988, following the government’s White Paper on electricity sector privatisation, the CEGB withdrew its modest share in fast breeder R&D (Patterson 1990, 11). A few months later, in July 1988, the Energy Secretary Cecil Parkinson declared that the government would stop paying the £50 million a year net running costs of the PFR and that the associated annual R&D expenditure would be cut from £51 million in 1988-89 to £10 million a year from 1990-91 – a level which would enable continuing UK participation in the collaborative work with France and Germany on the EFR (HC 119, 1990, paras 2 and 3). The total annual government spending on FBRs was therefore cut to a tenth. Funding for the PFR would cease after 1994, and for Dounreay reprocessing after 1997, hence bringing the FBR programme to an end. (Patterson 2010, 87) According to our AEA interviewee, the BNFL was desperate not to completely quit international cooperation and therefore put on the table £5 million per year for this purpose – this funding was subsequently reduced to £1 million and finally discontinued completely in 2006.

Judd and Ainsworth (1998, 615) interpret the Thatcher government’s policy towards FBRs by stating that while still recognising “the long-term need for fast reactors, it believed that the technology had been proved”, and that rather than being funded by the taxpayer, the further development should henceforth be the responsibility of private industry on a strictly commercial basis. Parker and Surrey (1995, 842), in turn, summarise the rationale behind the government’s decision to cease funding to FBRs, relying largely on material from subsequent reports from House of Commons Energy Committee providing advice to the government: the world uranium resources would last for at least 75 years and the UK would not need an FBR for at least 30-40 years; participation in the European collaboration was costly; the political support for the FBR was waning; for FBRs to become economic, thermal reactors in the UK would first need to become competitive with alternative energy sources – unless world thermal reactor capacity was expanding sufficiently to force the extremely large rise in the price of uranium needed to make FBRs economic compared to thermal reactors

and unless the public accepted the widespread installation of plutonium-fuelled FBRs; and FBRs were not needed to guarantee energy security in the UK.

Parker and Surrey (1995, 842) described the last phases of decision-making on FBRs: While continuing its support to the EFR collaboration, the government nevertheless said that it would review its position in 1993, when the Concept Validation Phase of the EFR was expected to end. The government also would expect the utilities and/or the industry to carry the major responsibility for the possible preconstruction phase of the EFR. Soon afterwards, the British electricity supply industry was privatised, its R&D was cut to a fraction of its former level, and the commercial interest for the EFR in the UK, Germany and France was vanishing.

### 5.3 Explaining Thatcher government's decisions on fast breeders – economics, ideology, and politics

In their analysis of UK nuclear policies during the Thatcher era, Parker and Surrey (1995, 835) conclude that “[n]uclear power policy was dominated from 1979 to 1987 by the intention to build PWRs, but from 1988 onwards it was dominated by the financial liabilities resulting from decisions made long before 1979.” Contrary to the situation that had prevailed until the early 1970s, and to a certain extent up until the entry in power of the Thatcher government in 1979, fast breeders were no longer at the centre of UK’s nuclear policy. While the economic viability of nuclear power in general, and fast breeders in particular, had come under increasing criticism already since the latter part of the 1970s, the failed privatisation of the nuclear industry in 1989 brought about a more fundamental change. It was then that nuclear energy proved to be uneconomical in light of new cost calculation criteria, triggering a shift in argumentation by the government from the claim that nuclear was economical in the short and medium term, to the claim that it brought significant environmental and long-term security of supply benefits, and would indeed be economical when the price of fossil fuels would increase and the environmental externalities of fossil fuels would be integrated in cost estimates (Parker and Surrey 1995, 843).<sup>45</sup>

Clearly, economic concerns and cost calculations took the centre stage in debates on British energy policy from the late 1970s onwards, with the election of Margaret Thatcher in 1979 marking a key turning point. While by no means an unconditional supporter of government energy policy, Henney (1994, 12)<sup>46</sup> nevertheless encapsulated the ethos that prevailed in the 1980s and early 1990s in the UK energy policy, arguing that the major reason for the demise of the coal and nuclear policies was the revelation of the “economic reality” of the policies practiced thus far. Henney made a parallel to Churchill’s well-known statement about democracy as the “least-worst” option, arguing that while markets “*are not perfect and they are generally uncertain and messy, and sometimes chaotic and painful*”, they are nevertheless “*preferable to politicians, civil servants and supplicants for public patronage at*

<sup>45</sup> In particular, Prime Minister Thatcher had spoken on the world stage about the dangers of greenhouse effect, and evoked nuclear power as a means of addressing the problem.

<sup>46</sup> Indeed, while keen to retain his independence and freedom of opinion, a few years earlier Henney had produced a report for the Greenpeace (Henney 1989), in which he heavily criticised the government’s policy on nuclear energy.



*public expense. The wise energy policy is to liberalize markets and then correct for defects - but the experience of past failures shows that public policy should be discussed in an open manner with the numbers on the table.”*

Hence, Henney's statement captures two key demands prevailing in the UK energy policy and society at the period: greater openness and closer economic scrutiny. What was probably characteristic to the UK, was the combination of the two; the primary function of openness was seen to be that of revealing the economic ‘truth’ about nuclear, not the safety failings of nuclear industry, for example.

#### 5.4 ‘Pure’ economics or political interests and strong personalities? Coal industry, miners’ strikes and leaders of the UK nuclear establishment

While it would be tempting to interpret the evolution of UK policy on nuclear in general and fast breeders in particular under the Thatcher government from the angle of mere economic rationality – that the government's main mission was to introduce economic and financial accountability into the nuclear policy – this would be to overlook at least two other crucial factors. First, while fundamentally driven by an ideology of free market liberalism and economic efficiency, Thatcher was certainly motivated just as much by the political objective of crushing the power of the coal miners' unions. According to Parker and Surrey (1995, 846), the policy of the Thatcher government “was to expand nuclear power in part if not wholly as a means of achieving the political agenda on coal.”<sup>47</sup> In other words, for Thatcher, nuclear power was a crucial alternative to coal: reduction of the importance of coal in the national energy mix would also reduce the power of the coal miners unions. Hence, Parker and Surrey refer to the disparity of treatment between coal and nuclear: while coal was judged on conventional economics basis – equated with all other commodities – nuclear was considered as an asset of strategic security and therefore continued to enjoy special treatment.

Importantly, strategic security was not defined in terms of import dependency, but as an attempt to minimise possibilities for electricity supply disruption that the recurrent coal miners’ strikes had brought about. Furthermore, Henney (1994, 11) asserts that “British Coal's unreliability was a major cause of the CEGB's wish to build PWRs – Arthur Scargill<sup>48</sup> – was nuclear power's best advocate.” He further claims that the “CEGB wanted to reduce its dependence on British Coal and many of the engineers were obsessed with building PWRs” (Henney 1994, 7). The desire to crush the miners was certainly an important motivation for the haste at which the government pushed the construction of thermal nuclear plants, and thereby probably at least precipitated the fall of the fast breeders. As political priorities had shifted to the need to tackle the trade unions, fast breeders no longer served a useful purpose.

<sup>47</sup> Winskel (2002, 462) notes the Energy Secretary Nigel Lawson’s remark that ‘the need for “diversification” of energy sources . . . was code for freedom from NUM blackmail’: Nigel Lawson, *The View from No. 11: Memoirs of a Tory Radical* (London: Bantam, 1992), 168.

<sup>48</sup> A vocal opponent of Thatcher’s policies, Scargill was the President of the National Union of Mineworkers (NUM) from 1982 to 2002, and led the union through the 1984–85 miners' strike.



The second non-economic consideration relates to the role of strong personalities in directing the policies. It has not been possible, within the framework of this research, to conduct careful analysis of the role that key personalities – notably the leading figures at the AEA and the CEGB – played in shaping the policies. However, the somewhat patchy evidence available suggests that action by leaders such as Christopher Hinton, John Hill and Walter Marshall indeed was pivotal in shaping the evolution of British fast breeder policy. The UK fast breeder history provides examples of more or less failed attempts by the government to promote its own policy agenda by nominating their favoured powerful individuals in key positions. An early illustration was the nomination of Christopher Hinton as the first chairman of the CEGB. Patterson (1985, 6) argues that unlike the government thought when appointing Hinton, “the brilliant engineer who had overseen the creation of Britain's nuclear-weapons facilities” (Patterson 1985, 6), Hinton became one of the early ‘doubters’ of the extent of UK’s nuclear programme, and later of the FBR programme. According to Patterson (1985, 6), this was because Hinton was committed to “sound engineering – including economic engineering”. Hence, in March 1977, Hinton noted: “Most of the mistakes (and fortunately they have been rectifiable) on PFR have been made because engineers have thought they were just that little bit more clever than any of us really are” (Patterson 2010, 81). Similarly, the nomination of Sir Brian Flowers to chair a RCEP committee to examine Britain’s nuclear policy in 1975 was thought to give fast breeders a boost. In reality, the Flowers report became an ‘instant bestseller’ as the first official high-level report casting serious doubts about the reasonableness of the fast breeder programme and highlighting the problems of nuclear waste and proliferation.

Thatcher government's decision to nominate Walter Marshall, first as the head of the AEA in February 1981, and then of the CEGB from July 1982 (Patterson 1985, 57, 61) was probably crucial in helping the government push through its liberalisation policies while at the same time supporting nuclear power. However, even so, the forces unleashed by these decisions seemed to escape the control of the government. Marshall was known as a key figure within the British nuclear lobby, having been sacked in 1977 from his position as a Chief Scientist of the Labour government, presumably at least in part as a reaction to his excessively eager support of the PWR technology (Patterson 1985, 45). However, Thatcher and the Energy Secretary Nigel Lawson saw in Marshall a useful ally in promoting their nuclear policy.

According to Patterson (1985, 57), Thatcher – as well as the “fast breeder enthusiasts” – particularly appreciated Marshall's “aggressive and outspoken style of leadership”, but this very same approach also aggravated the existing controversies within the nuclear establishment. Perhaps even more crucially, as Winskel (2002, 457) argues, *“the deeply held pro-nuclear convictions of both Marshall and Thatcher... undoubtedly obscured appreciation of the wider institutional and economic forces released by the liberalization proposals.”* Hence, it was only when “the escalating cost estimates threatened the entire ESI sale that the Government abandoned its allegiance to the technology.” (ibid.)

### 5.5 Withdrawal of the UK from international fast breeder collaboration (early 1990s)

Two years after taking office, in November 1992, the Prime Minister John Major's conservative government declared that the UK would withdraw from the European fast breeder collaboration. The cutback in government support for the FBR programme was expected to lead to 400 to 600 job losses at AEA Technology centres at Risley, Winfrith, and Harwell (Nuclear News, 4 December 1992). The Energy Minister at the DTI, Tim Eggar, justified the decision in his address to the House of Commons stating the project "was not a priority" for the government, and that it had consulted the British nuclear industry prior to making the decision. By contrast, the UK's decision took by surprise its French and German partners, who complained about not having been consulted in advance (Europe Energy, 4 December 1992).

In the UK, there was some opposition to the backing out. The trade unions and the opposition Labour Party urged the government to proceed with FBR research in order to secure the UK's future in the energy sector. However, the government claimed that the decision would save British taxpayers almost £13 million per year (Europe Energy 1992). Over forty years, British taxpayers had spent an estimated £4 billion on FBR research (Europe Energy, 4 December 1992).

### 5.6 Shut-down and decommissioning at Dounreay (mid-1990s)

Judd and Ainsworth (1998, 616) note, with some bitter irony, that at the end of March 1994, "PFR was finally shut down, after one of its most successful years with a load factor over 80%". With equal sarcasm, the Independent newspaper (Buchan 1993), sceptical towards nuclear energy in general, reported just a few days after the closure of the PFR in 1993 that the closed reactor "generated from its only functioning fast reactor enough electricity to light up the city of Aberdeen", and continued that in 2001 "there will not be 10 000 MW of plutonium electricity in the British grid" [as the Windscale Inquiry report fifteen years earlier had predicted], "but none". The same newspaper article quoted Dr Christine Brown of AEA Technology saying that she was "absolutely convinced that a commercial fast reactor will be in operation within 25 years" (Buchan 1993).

Reprocessing of irradiated fuel came to a halt in 1996, following a plant breakdown which the government in 2001 decided not to repair. By 1995 all the fuel had been removed from the PFR. Judd and Ainsworth (1998, 616) expected the "[f]irst stage decommissioning, with the sodium and NaK removed and disposed of, the reactor prepared for long-term storage, and all the fuel reprocessed", to be completed by 2001. The original timescale for decommissioning of 100 years has been reduced steadily. In 2008, Dounreay Site Restoration Ltd, the company managing the clean-up on behalf of the Nuclear Decommissioning Authority (NDA), estimated the total cost of the project at £2.5 billion (undiscounted), with the expected end-date for the clean-up 2025 (NDA 2008). The project is funded and regulated by the UK Government through statutory bodies such as the NDA, the Scottish Environment Protection Agency, the Nuclear Installations Inspectorate of the Health and Safety Executive and

the Office of Civil Nuclear Security. The project continues to be a significant employer in the region, employing in 2008 some 2000 people, i.e. about 20% of the local workforce.(ibid.). After 2025, hazardous intermediate-level waste is to be stored above-ground pending a national policy for its long-term management. Access to areas contaminated with radioactivity is likely to be restricted until 2300.<sup>49</sup>

## VI. EXPLAINING THE RISE AND FALL OF THE FAST BREEDER PROGRAMME

After the chronological description of the UK fast breeder development from the early days of the nuclear programme, when the fast breeder was seen as the flagship project of the nuclear industry, to the eventual termination of the programme in the 1990s, we shall in this section seek to explain the reasons for the trajectory of advancement of the FBR projects in the UK. A number of key elements and explanations put forward by our informants and found in the literature will be examined in more detail. One of the most fundamental among these are the forecasts and predictions about the electricity demand and the potential of fast breeder reactors, both of which were repeatedly revised downwards during the course of the years. Another key topic of debate was the nature of the problems encountered in FBR development: to what extent were the difficulties inherent to the technology itself as opposed to being provoked by ‘external’ factors and events. As we shall seek to demonstrate, the external-internal distinction is largely a false debate: the viability of a technology cannot be meaningfully judged in isolation of the broader environment within which it is developed and applied. Nevertheless, the demise of the fast breeders was frequently blamed on what were perceived as ‘external’ factors – be they technical problems presumably unrelated to the ‘core’ of fast breeder technology or factors external to the broader system of fast breeders such as the declining uranium and energy prices, the oil crises, nuclear accidents and incidents unrelated to fast breeders, or presumably excessive concerns about proliferation risks associated with the planned ‘plutonium economy’. Obviously the role of and the relations between key actors in the area were crucial in shaping the development of the FBRs, the gradual loss of power and autonomy of the AEA being a key explanatory factor. More generally, the problems encountered by the UK nuclear sector especially in the 1970s were often attributed to institutional failings, the fast breeder advocates frequently criticising what they perceived as the absence of a coherent industrial policy in the country. Among the most significant factors explaining FBR developments in the UK was the sharp shift in the political environment with the entry in power of Margaret Thatcher, and the subsequent doctrine of economic liberalism. On the one hand, the ‘free market fundamentalism’ profoundly changed the criteria against which the performance and potential of energy technologies in general and nuclear energy in particular were assessed, while on the other hand Thatcher saw no place for FBRs in her political ambitions of bringing down the power of the coal miners’ unions. Finally, the public opposition against fast breeders seemed surprisingly weak in the UK, especially against the background of a rising concern about nuclear energy in general and reprocessing in particular. However, this general opposition against the ‘nuclear complex’ clearly played an indirect role in weakening the nuclear industry and

<sup>49</sup> [http://en.wikipedia.org/wiki/United\\_Kingdom\\_Atomic\\_Energy\\_Authority](http://en.wikipedia.org/wiki/United_Kingdom_Atomic_Energy_Authority)

thereby making it more difficult for FBR advocates to push for their preferred technology.

### 6.1 Forecasts, predictions and expectations

The history of UK fast breeder programme has been marked by an evolution from the highly optimistic, even fantastic expectations concerning the cost, technical performance and rate of construction of fast breeder technology, towards gradually more realistic and increasingly pessimistic estimates as experience was gained on the actual operation of the fast breeders. For example, the select committee on science and technology simply declared in its first report in October 1967 that fast breeder reactors were “likely to provide a very cheap source of electricity” (Patterson 2010, 76). The committee expected building costs (at 1967 prices) of fast reactor stations as low as £50 per kilowatt installed and generating costs falling to 0.3d [old pence] per kilowatt hour (ibid.) This conclusion was partly based on the assessment by the AEA, which in its 1965-66 annual report had concluded that the capital costs of a commercial fast breeder reactor would be “similar to that of the best thermal reactor available at the same time, with potential for further reductions” (AEA Annual Report 1965-6, paragraph 157). A decade later, at a conference on energy policy and fast breeders held in London in November 1978, when the introduction of commercial fast breeder reactors was at the centre of nuclear policy agenda, the Deputy Chairman of the AEA, Walter Marshall, presented a first cost estimate, arguing that the AEA “figures were of the same order of magnitude as the French estimates for the cost of Superphénix, i.e. about 60% above the cost of French LWRs (Pearson 1979, 77).

The predictions about the likely contribution of fast breeders to UK electricity supply were continuously corrected upwards in the late 1960s and early 1970s. Hence, in 1968, the AEA estimated that FBRs would provide at least 15 GWe of electricity by 1986, while Valéry (1974) reported, in the aftermath of the first oil shock, that it would not be unrealistic to expect that by the end of the century, 25% (up to 40 000 MW) of UKs electricity might be generated by fast breeders. A year later, in its submission to the “Flowers committee”, the AEA expected at least 33 GWe of the total generation of nuclear electricity 104GWe in 2000 to come from fast breeders (RCEP 1976, 179). According to our interviewees, the AEA had in fact already cut its original estimates by half before submitting its views to the committee, simply to ensure that the forecasts appeared realistic. Patterson (1985, 38), in turn, reports that the chairman of the committee, Sir Brian Flowers, “apparently took issue with this surreal suggestion”, leading the AEA to quickly pull back, claiming that these figures did not represent a forecast, but “merely an upper limit for analytic purposes”. However, still a year after the release of the Flowers report, Cutts (1977, 245) predicted up to 80% participation of nuclear in the UK electricity supply in 2020, the majority of which would be derived from fast reactors. In particular, Cutts argued against postponing the fast breeder programme, because any delays would significantly reduce the potential savings in uranium resource.

The timetables foreseen for the construction of fast breeder reactors were equally ambitious and later turned out to be unrealistic. In the early 1960s, a large-scale commercial fast breeder programme was expected to be in operation by the early

1980s (Herbert 1962). In the mid-1960s, the industry reported that fast breeder reactors would be on-line by 1971 (Sweet 1990, 408). Sweet (1990, 408) notes that two years after this had not happened, yet the industry projected the future of an 'All Electric Economy'.<sup>50</sup> In October 1970, the AEA (John Hill) expected the construction of the first civil fast reactor, of possibly 1300 MW, to start by early 1974. In its annual report one year later, the AEA confirmed the plan to start the construction of a "lead station" in 1974, which would be followed by the construction of other stations at perhaps two years' interval (Patterson 2010, 76-77). At the same time, the CEBG remained hesitant. Hawkes (1971, 682) hence underlined the optional nature of the plans, referring to a statement by a CEBG spokesman: "What we're saying is that we could order as early as 1974. That would mean we would be commissioning the first station round the turn of the decade."

Notwithstanding the official position within the 'nuclear establishment' in these early years of British nuclear policy that fast breeders were the ultimate and logical culminating point of nuclear energy policy, there were dissenting views even among the 'insiders'. The inflated expectations of the late 60s and early 70s were therefore partly in contrast with the relative cautiousness of many pioneers of nuclear power. Winskel (2002, 442) notes that these pioneers – such as Christopher Hinton – were often sceptical particularly about the economic competitiveness of nuclear electricity. For instance, as early as 1950, during a period when the need to develop fast breeders was allegedly nearly the only topic subject to consensus among the British nuclear energy community, the head of the research institute at Harwell, Lord John Cockcroft recognised the technical challenges and complex chemical engineering tasks involved, which could mean that the reactors "may take a considerable time to develop into reliable power units" (Cockcroft 1950, 33019). Perhaps unsurprisingly, such scepticism was more widespread among the engineers involved in the practical construction of nuclear installations than among the nuclear scientists conducting basic research and developing new technologies such as the fast breeders. Hence, AEA engineers working at Risley expressed their doubts in 1953, noting that the "fantastic" yet "unrealistic" FBR scheme and that "[i]t might well be argued that it could never become a serious engineering proposition" (Patterson 2010, 74). On May 9 1962, Sir Christopher Hinton, at the time head of the CEBG, told the House of Commons Select Committee on the Nationalized Industries, 1962-63 that he thought progress at Dounreay had been "disappointingly slow", and that he did not feel at all confident about predicting when the technology might be mature enough to deliver a solution (Patterson 1977, 24). Herbert (1962, 338) indirectly alludes to the early disillusionment in among the nuclear establishment in noting that the Dounreay experimental reactor may finally be on the verge of resolving the long-drawn problems, which could help to recover "the lost excitement and wonder of harnessing the energy of the atom".

However, the early scepticism seemed to soon give way to inflated expectations in the 60s and early 70s – a period of great expansion of the AEA staff, when the AEA was virtually independent from any outside control, and therefore presented, according to one of our interviewees, "a wonderful environment" to do research on fast breeder technology. According to this informant, the great change came only with the entry in

<sup>50</sup> L. Brookes, 'Towards the all electric economy', *Atom* (UKAEA), 202 August 1973.



power of the Thatcher government, whereas others – including many of our interviewees – pointed at the gradual loss of credibility of the fast breeder programme during the 1970s, and notably the reorganisation of the AEA in 1971.

The highly optimistic forecasts were, however, progressively being called into question and revised from around mid-1970s onwards. This rethinking and the relatively rapid and accelerating erosion of trust in FBRs during the 1970s were triggered by many reasons such as the stagnation of electricity demand following the oil crisis and the economic stagnation in the late 1970s, the technical problems with the fast breeder reactors, and the decline in oil and uranium prices in the 1980s. However, a key factor was the change in the “goalposts” of economic appraisal, initiated during the course of the 1970s and reinforced with the privatisation of the electricity industry. According to an AEA informant, the great change came only with the entry in power of the Thatcher government, whereas others – including many of our interviewees – pointed at the gradual loss of credibility of the fast breeder programme during the 1970s, and notably the reorganisation of the AEA in 1971. Sweet (1982) described the radical change concerning the assumptions underpinning the forecasts noting that the increasing uncertainty had brought economic arguments to the centre stage – implying that investment decisions should be underpinned by a careful analysis of the costs and risks involved. Sweet highlighted the drastic change in the methods of forecasting and modelling for the introduction of FBRs, which had until the late 1970s been dominated by the assumptions that high breeding gains and short doubling times (7-14 years were common to many models) were primordial, and that capital costs of FBRs would be at most marginally higher than those of thermal reactors. Sweet (1982, 18) mentions as a typical example of the new thinking the criticism by the House of Commons Select Committee in 1980<sup>51</sup> against the industry’s “preference for using historic costs rather than replacement costs, and for using such cost trends in extrapolating future requirements”, which had allegedly “led to a wide divergence between published costs and real costs.” By the early 1980s, it was broadly accepted in most countries considering fast breeders – France being a notable exception – that FBRs breed “only slowly, that doubling times have no great significance and that the early introduction of the fast reactor is either impossible or unwise” (Sweet 1982, 18).

Finally, it is worth noting that still in the late 1990s, fast breeder advocates saw the technology as an inevitable culmination of nuclear energy, with Judd and Ainsworth (1998) concluding that around 2050 “the main emphasis will be on breeders”. Simnad (1998) summarises the enduring belief of fast breeder advocates in FBRs as a solution for the world’s energy problems, in the context of ever-increasing needs:

*“We are now at the threshold of large-scale commercial acceptance of FBRs within the next few decades in many countries, in order to meet the tremendous increase in energy demand anticipated for the next century. The combined forces of a doubling of the world’s population and increasing per capita energy consumption to achieve economic growth will require a solution to the problem of providing an acceptable and abundant long-term energy supply.”*

<sup>51</sup> House of Commons Select Committee on Energy, *Report on the Government Statement on the New Nuclear Programme*, HC114-1, HMSO, London, 1980



## 6.2 Technological Arguments: problems inherent or external to the technology?

Arguments evoking the inherent viability (or unviability) of the technology were central in the discussion on fast breeders in the UK, and were clearly manifest in our interviews. These positions and opinions range between the two extremes from the view that the fast breeder technology is fully tried and tested to those considering fast breeders as nothing but another unrealistic engineering dream, plagued with irresolvable technical and safety problems.

Examples of the view that the fast breeder technology is inherently viable, tested, and safe came from the former AEA scientists and engineers. One of them admitted that FBRs were undoubtedly more difficult to operate than the thermal reactors, with the use of sodium as coolant as among the most crucial of such difficulties. However, as the fast breeder proponents repeated at numerous occasions throughout the years, these problems were by no means inherent to the FBR technology or the nuclear fuel, but would be ‘conventional’ problems related notably to the materials used in the reactors. According to one of our AEA interviewees, when it comes to basic reactor physics, “the FBR technology works”. And yet, it was precisely this argument of FBR technology as “proven” that was used as an argument by the government to discontinue funding the fast breeder development in the 1980s. If the technology was already proven, it should be up for the industry to decide whether or not to launch a commercial-scale FBR programme. By contrast, Patterson (2010, 80) counters the argument about the technical problems as merely ‘ancillary’ by noting: “If you could not then use the molten-sodium reliably to boil water, you had a basic design problem – one that could not be brushed aside by reference to the satisfactory operation of the reactor core itself.”

The ‘internal vs. external’ discussion had another manifestation in the discussion on reactor safety, another topic on which even the advocates of nuclear energy were divided. One of our interviewees referred to the safety concerns among a ‘significant minority’ of members of the ‘nuclear community’, stemming largely from the difficulty of controlling the Dounreay reactor.<sup>52</sup> A former AEA scientist, in turn, contested the view that fast breeders would suffer from particular safety problems, but argued instead that safety had been largely proven: both the pilot and demonstration plants have had a satisfactory safety record and performance – or at least, there have not been accidents comparable to Chernobyl or even the Three Mile Island.

For the majority of the interviewees, there was an intimate link between technology and economics. Hence, the technological argument was rephrased in the following terms: the fast breeder technology entails inherent characteristics that make it virtually impossible to bring its cost below that of the thermal reactors. From this perspective, the technological argument alone would be irrelevant for practical decision-making, because in the face of the uncertainty about the evolution of different alternative energy technologies, it would be of little relevance whether the fast breeder technology could be made operational in the long term.

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<sup>52</sup> For example concerns related to the issue of ‘void coefficient’.

### 6.3 External factors

A common explanation for the failure of the fast breeder programme, used especially by the AEA scientist and engineers, made reference to “external” factors that hampered the development of the fast breeders. These explanations can be seen as an extension of the argument that the FBR technology itself was completely viable, but that the threats and problems came from various ‘external’ sources. At the centre of the debate were the varying interpretations of what exactly was external and ‘internal’ to the technology.

#### 6.3.1 Uranium prices

The availability of uranium, and especially its price as an indicator of scarcity, featured prominently in all of the explanations to the evolution of the fast breeder programme. As explained by one of our interviewees, for the first, a feature common to the debates on nuclear power in general, the “uranium argument” has been used both by the advocates of fast breeders and the critics of nuclear energy. For the former, the unavoidable increase in uranium prices makes fast breeder technology an essential element of nuclear energy, while the latter use the argument of the limits of uranium resources as a proof of the unsustainability of nuclear energy.

The decline in the world uranium prices was evoked by most of our interviewees as a major reason for the falling support for fast breeders. These discourses portrayed this evolution variously as a mere confirmation of the unviability of fast breeder technology, or as an “external” factor disturbing the long-term vision needed to develop a technology vital for the future of energy supply. In any case, by the late 1970s, the situation concerning the availability and price of uranium had changed dramatically. The AEA predicted, in the mid-1970s, that uranium prices would increase to USD 100-200 per pound when all the high-grade uranium would have been committed to existing nuclear programmes in the 1990s and concluded that fast breeders should be built as quickly as possible (Merrick, 1976, 597). The CEGB, by contrast, argued that the main justification for fast breeders was not economic, but their ability to reduce the need for uranium in the long term – important because the resources might turn out to be limited (*ibid.*). Buckley et al. (1980) argued that reserve estimates were rising rapidly, demand growth was being cut back, and higher grades of ore and less expensive exploration techniques were expected to further reduce the price of uranium in the 1980s and lower the long-term price expectations of internationally traded uranium.

While the anticipated rise in uranium price has always been a major rationale evoked by the supporters of FBRs, one of our interviewees sarcastically noted that the timing for such a price increase always seemed to be “ten years away”. In reality, already in the 1980s, uranium prices had declined low enough to render the price argument difficult to sustain (e.g. Walker 2000). One interviewee, a nuclear economist, provided recent evidence to support his view that the “uranium argument” continues to be untenable. Firstly, around 2000, a lot of Russian highly-enriched uranium from

its military installations came to the market and contributed to the decline in world uranium prices. Hence, today uranium accounts for only 2-3% of the life-cycle cost of nuclear energy. Another interviewee, an economist, argued that even a ten-fold increase in uranium price would not suffice to make fast reactors an economically viable option. Secondly, the “nuclear renaissance” – be it real or imaginary – has led a number of utilities to forward-contract uranium; since uranium is a compact source of energy and therefore very easy to store, most utilities keep a couple of years’ stock of uranium and thereby protect themselves from the widely fluctuating spot prices of uranium. Thirdly, the real price of uranium has remained essentially unchanged over the past 50 years. And fourthly, the volumes of uranium needed to run nuclear power stations are relatively small; for instance, one month’s production from a single mine in Australia could satisfy the entire world demand for uranium for a year.

Finally, as Papadopoulos (1981, 320) reminded, the interaction between uranium price and fast breeder development goes both ways: especially in the 1970s and 1980s, the widespread development of fast breeders would have influenced uranium price expectations.

Regardless of the ‘facts’ or the ‘reality’ concerning the availability and future evolution of uranium prices, the declining prices and the slowing down of thermal nuclear programmes certainly contributed to reducing the urgency to bring down uranium demand through the development of fast breeders. This explanation was indeed evoked by most of our interviewees.

### 6.3.2 Oil crisis

The first oil crisis (1973-74) had somewhat ambiguous consequences for the UK fast breeder programme. On the one hand, it reinforced the argument that nuclear power was needed as an alternative to fossil fuels. Given the central position of fast breeders as the logical end-point of the development of nuclear power, especially the first oil crisis therefore gave further impetus also to the development of fast breeders. However, the urgency to deploy readily available alternatives to oil led to a shift in priorities within the nuclear sector: long-term R&D on fast breeder technologies progressively gave way to the pressing need to build thermal reactors that would help to reduce oil dependency in the short to medium term. According to Patterson (2010, 85), from 1978 onwards, PWRs became the chosen technology, hence replacing AGRs and “tacitly sidelining the fast breeder”. Despite the short revitalisation of the support to fast breeders in 1979, as a result of Thatcher’s entry in power, the attention soon shifted again to the thermal reactor programme. For example, in 1981-82, the main focus of nuclear controversy was on the PWR Sizewell B, not on fast breeders (Patterson 2010, 85).

Finally, the oil crisis and the subsequent economic stagnation led to a significant downward adjustment of electricity demand scenarios, reduced the urgency to build new capacity, and thereby pushed the need for the fast breeder further into the future.

Furthermore, while a similar shift in priorities away from fast breeder research to the construction of PWRs took place in France, the French advocates of fast breeders

benefited from the energy policy context that was different from that of the UK. The French “*tout pétrole*” policy that had preceded the oil crisis and the scarcity of alternative domestic energy sources made it easier to launch a massive nuclear programme, thereby helping the “nuclear establishment” to retain and reinforce its power. The UK, by contrast, possessed seemingly abundant and cheap domestic energy sources, notably coal and North Sea gas and oil. Consequently, the urgency to construct thermal reactors and the ability of the nuclear establishment to retain its power – let alone acquire a hegemonic position – were considerably weaker than in France.

### 6.3.3 Risks, safety and security: radiation and proliferation

One of the lines of argument employed by many of our interviewees mentioned the increasing safety and security concerns as a major reason for the decline of the fast breeder programme. From this perspective, risk regulation was perceived as an ‘external nuisance’ that stemmed from concerns that had little if anything to do with the fast breeder technology. The key events can be classified into nuclear accidents on the one hand – the Three Mile Island and Chernobyl accidents probably being the most influential – and the recurrent technical problems in fast breeder technology (fires, interruptions in the operation of the plants, etc.) on the other. While fast breeder reactors had not suffered from major accidents, the Three Mile Island and Chernobyl accidents increased public concern, eroded public trust in nuclear technology, and led to stricter safety regulations and greater outside scrutiny also in the development of fast breeders. However, by the time these accidents occurred, the UK nuclear industry in general and support for the fast breeder project in particular had already weakened to an extent that the accidents mainly accelerated the decline already underway, rather than being its main cause. Nevertheless, according to our AEA interviewees, the increasing scrutiny and strengthening of the safety regulations fuelled frustration among the scientists and engineers, who no longer had the freedom they used to have in the past to develop new technologies.

The logical sequence of the argumentation from accidents to the decline of fast breeders can be summarised as follows:

*accidents, incidents – public and media attention to risks – safety and security becomes a politically sensitive topic – tighter safety regulation – increasing economic costs – erosion of the economic viability of fast breeders*

The interviewees obviously portrayed differently the different elements of the sequence. Firstly, while all saw the accidents and ‘incidents’ crucial in shaping public and political opinions, the ‘true’ nature of such events was seen differently. On the one hand, a former AEA scientist seemed to belittle their seriousness, referring for example to Three Mile Island accident as a mere ‘incident’. Others saw in the large number of incidents a proof of the problems inherent to a technology excessively complicated “just to boil water”, as one of our interviewees put it. Consequently, the rise of safety and security on the political agenda was interpreted either as welcome sign of an increasing ‘awareness of the problems’ or as unjustified ‘public outcry’

stemming from the lack of understanding about the underlying technical matters. An AEA interviewee recognised the value of tighter safety regulation, but nevertheless lamented the lack of proportionality in the matter. Another AEA interviewee regretted the deleterious effects on engineers' morale from the fact that they should today spend so much of their time in 'preparing the safety case' instead of doing the 'real' work, i.e. developing the technology. Finally, as for the economics of fast breeders, the rising costs – but especially the increasing attention brought to the economic performance of the technology – was portrayed either as an 'awakening' to the 'realities' or as an outside intrusion, which distracted the process of long-term R&D necessary to bring fast breeders into being.

The comment by a former Friends of the Earth activist, in our interview, characterises the criticism against the hypothesis of 'external events' behind the fall of the FBR programme: *"The surprising thing is that people always assume it was outside agencies that crippled the FBR program. But it was the fact that it was a flawed technology."* Winskel (2002, 457), in turn, abstains from the assumption about the possibility of a technology being inherently 'flawed' or 'viable', and encapsulates the ethos of the autonomy of technology, which was prevalent among nuclear engineers still in the 1970s. This perspective was based on the premise that the nation's best interests could only be damaged by an unjustified external intrusion into the development of technology:

*"Marshall, and others, never wavered in their beliefs that, so long as they were freed from 'political interference' or 'short-term market concerns', nuclear engineers would 'get the technology right' – axiomatically, doing what was best for the industry and country."*

## 6.4 The role of policy actors and policy entrepreneurs: AEA and CEGB

### 6.4.1 Role of the AEA: from hegemony to decline and loss of mission

The AEA played a pivotal role in advancing the fast breeder technology in the UK, and the development of fast breeders constituted the core mission of the AEA long into the 1960s. In a manner similar to that of the CEA in France, the AEA occupied at that time a nearly hegemonic position in the UK. While there were attempts of what one of our interviewees called a "more logical structure" as well as to make the different units within the AEA self-standing and subject to the market discipline already in the 1960s, until 1971 the AEA continued to have comprehensive responsibility for civil and military nuclear R&D together with fuel and weapons production. In 1971, the AEA was broken up so as to separate the civil and military nuclear activities into separate organisations – a key turning point, which arguably initiated a period of decline for the AEA.<sup>53</sup>

Even after the split-up in 1971, the AEA continued to hold a monopoly of civil nuclear R&D including early prototype development and was also the major source of

<sup>53</sup> In the reorganisation, the BNFL became the sole supplier of fuel-cycle services to reactor operators (Walker 2000, 842).

high-level technical advice to the government (Rush et al. 1977, 96). And yet, AEA failed to ever gain the hegemonic status that the CEA – or more broadly, the “Corps des Mines” – enjoyed in France.

The gradual decline in the political power of the AEA was on the one hand one of the main reasons for the decline of the fast breeder programme, while at the same time being itself a consequence of the general loss of support to fast breeders. The mutual interaction between the decline of AEA’s power and the declining support for fast breeders took many forms, some of which are illustrated in the following.

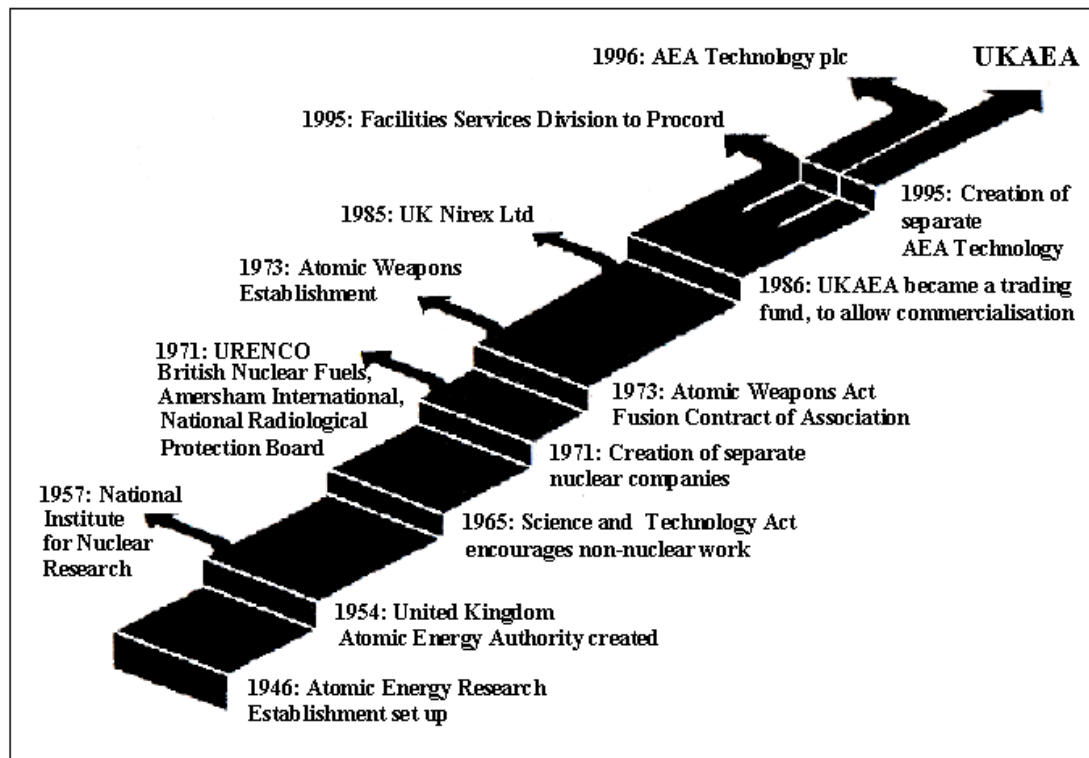
A further factor weakening the AEA and the fast breeder project was the growing feeling of disappointment and disillusionment, even amongst the nuclear scientists and engineers, at the slow progress of the project. Since the grandiose plans and expectations from the 50s and 60s failed to materialise, this affected the morale within the AEA, as noted by our AEA interviewees. This, in turn, contributed to a “brain drain” of sorts, from AEA to the CEGB, the latter being perceived by the scientists and engineers as the place where the real decisions on nuclear energy were made. The AEA staff was drastically reduced from the over 40 000 in the early 1960s and keeping the best ‘brains’ in the organisation became an acute challenge for those responsible for implementing the policies of personnel reduction. According to our AEA interviewee, the introduction of commercial accountability and project-based management principles in the early 1980s dented the morale of AEA staff, and took away a lot of the excitement that had been in the research until then. Consequently – still according to this former AEA scientist – in the course of the 80s, all members of the AEA fast breeder community came – at one point or another – to understand that their “times were counted”. The late 1980s brought further changes, as the AEA was “put into Trading Fund mode”, required to act and account as a commercial enterprise. Between 1988 and 1993, staff numbers declined from 13 600 to 8 300 (HSE 1998, v). In the 1990s the AEA was split again, with the more commercial parts transferred into a public company AEA Technology, subsequently floated on the London Stock Exchange, while the parts directly related to nuclear liabilities and decommissioning were retained at the AEA.<sup>54</sup> Only about 2 000 workers stayed in this government-owned part, then known as Government Division, which has meant that the AEA has had to buy a number of its key services from contractors (HSE 1998, v).

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<sup>54</sup> [http://en.wikipedia.org/wiki/United\\_Kingdom\\_Atomic\\_Energy\\_Authority](http://en.wikipedia.org/wiki/United_Kingdom_Atomic_Energy_Authority)



**Figure 5. History of AEA**



Source: HSE 1998, 8

Summing up the argument, the AEA was in the late 1970s and early 1980s well on its way towards losing its earlier central position, with some already envisaging the disappearance of the organisation. The AEA's successive failures to defend its preferred thermal-reactor technology (the AGRs, then the SGWHR) further contributed to the decline of the organisation in political power-play. This process had started already in the 1960s, but gained impetus in the somewhat chaotic atmosphere in which the UK nuclear policy found itself in the 1970s (GM). Our AEA interviewees likewise clearly portrayed the atmosphere of the 1970s in the AEA as one of declining self-confidence and the sentiment of rather bleak future prospects for the organisation.

Winskel (2002, 456) summarises the position of the AEA and its struggle to maintain its political clout and the reputation of nuclear energy in the context of persistent technical and economic problems faced by the technology:

*"...behind the façade of success and proclamations of growth and dominance, nuclear power was beset by chronic technical and economic problems. The failure to deliver cheap nuclear electricity meant that the AEA's role in ESI policymaking is more realistically seen, not as heroically unleashing an autonomous force, but as attempting to maintain the commercial credibility of British nuclear technology, and black-boxing the programme so as to retain its own institutional status and influence."*

In other words, Winskel refutes the argument of the autonomy of the technology, with its presumably inherent features and qualities, and underlines instead the central role

that the advocates and critiques of a technology play in constructing its viability, and thereby defending their own positions in the political process concerning technology development.

#### 6.4.2 Institutional arrangements

Collingridge (1984b, 46-47)<sup>55</sup> takes note of the relatively lively discussion concerning the role of the institutional arrangements as a central explanation for the poor performance of the UK nuclear sector in the 1970s and early 1980s. Williams blamed the poor accountability of public bodies in Britain, particularly the CEBG and AEA, a view shared by Henderson. Rush et al. (2011) as well as Franks and Patterson were concerned about the dominating position of the AEA as supplier of expert opinion and monopoly supplier of prototypes, and the secrecy surrounding much of its affairs. Sweet (1978; 1982, 26) suggested the establishment of an independent body to scrutinize estimates of nuclear costs, in particular to analyse the social costs and benefits of public R&D expenditure on fast breeders – not least to avoid the wastage of public funds on by continuing such funding simply to ‘buy peace’ once the AEA would be abolished. Wonder argued that the attention of bodies that might have been able to scrutinise the choices was constantly diverted from the technical issues of reactor choice to issues of industrial organisation. Rush et al. (1977, 105) acknowledged that unlike in the 1960s, nuclear policy – and fast breeder policy in particular – was in the mid-1970s subject to much greater public debate than earlier, with the AEA participating in the public debate through its own relatively detailed assessments. Yet, the authors argued that there was “still no wholly independent body in the UK for expertly and critically reviewing the exceedingly complex technical and economic aspects of alternative reactor programmes and for giving a second opinion on the UKAEA’s extremely authoritative advice.”<sup>56</sup> In particular, the RCEP was under threat of being dismantled (the RCEP was indeed ultimately abolished, but only 25 years later, by the Conservative-Liberal Democrat coalition government in 2011), and the Parliamentary Select Committee on Energy did not have the requisite technical expertise, resources and access to detailed technical information (ibid.).

Finally, and perhaps unsurprisingly, Hinton argued that the organisations making choices about nuclear development in Britain were not centralised enough. Pearson (1979) predicted that since the expected growth in future electricity demand failed to materialise, and trade unions were advocating more employment-generating energy

<sup>55</sup> Referring to the following documents: R. Williams, 'The structure of UK nuclear industry and its influence on policy', *Nuclear Energy*, Vol 19, 1980, pp 417-422. P.D. Henderson, 'Two British errors - their probable size, and some possible lessons', *Oxford Economic Papers*, Vol 29, 1977, pp 159-205. C. Franks, *Parliament and Atomic Energy*, D Phil thesis, Oxford, 1983. W. Patterson, *The Fissile Society*, Earth Resources Research, London, 1977. C. Sweet, 'Nuclear power costs in the UK', *Energy Policy*, Vol 6, No 2, 1978, pp 107-118. E. Wonder, 'Decision making and reorganization of the British nuclear power industry', *Research Policy*, Vol 5, 1976, pp 240-88. R. Williams, *The Nuclear Power Decisions*, Croom Helm, London, 1980, p 103 and p 245.

<sup>56</sup> While it is debatable whether a “wholly independent body” could ever exist on matters related to technology choice and development, the general point made by Rush et al. remains valid: the absence of credible “counter-expertise” on the technical and economic aspects of nuclear energy compromised the possibility of a reasoned debate on the benefits and disadvantages of nuclear energy in the UK still in the 1970s.

production methods than nuclear, the AEA would be forced to review its mission and reorient its activities away from fast breeder development.

#### 6.4.3 AEA: united or internally divided?

Most accounts of the events in the UK fast breeder history tend to describe the AEA as rather unified in its views, interests and argumentation. The picture painted by our AEA informants, but also by many other interviewees, was one of high level of agreement within the AEA about the fast breeder technology as the ultimate and logical objective of the organisation's R&D activity, and the desirability of work in this area even when the initial widespread support for fast breeders began to fade in the 1970s. The internal agreement and coherence of views within the AEA concerning the fast breeder technology may nevertheless not have been as strong as suggested by many. We have only scant evidence to back up this view, not least because many of our interviewees simply admitted their ignorance concerning the internal dynamics of the AEA – a further proof of the opacity of the AEA at the time.

However, the documentary material suggests that the picture was more complex than one of a unified front advocating FBRs. Gowing (1974, cited in Patterson 2010, 73) notes that the need for FBRs was the only theme on which there was general agreement among the AEA nuclear physicists in Harwell. The main reason for this unanimity was the scarcity and high cost of uranium: FBRs would solve the problem of access to the resource. However, as demonstrated by our historical survey into the UK fast breeder programme, there were influential 'sceptics' within the AEA, starting from its former chairman, Christopher Hinton. Moreover, a serious disagreement prevailed between the proponents of nuclear fusion on the one hand, and the fast breeder community on the other. These two communities within the AEA were portrayed by one of our interviewee as the worst enemies of each other, each one defending its own vision and preferred technology of the future.

#### 6.4.4 The AEA and the CEBG

While the AEA may have presented a relatively unified front in favour of the FBRs, conflict was very much established within the broader UK 'nuclear establishment'. Perhaps the most fundamental tension was that between the AEA 'scientists' on the one hand and the more practice-oriented and economy-conscious engineers within the CEBG. A prominent example of the CEBG's scepticism was a paper by Eric Carpenter, head of reactor physics at the CEBG's Berkeley Nuclear Laboratories, presented in an international conference on "Fast Reactor Power Stations" in March 1974. The paper took a highly sceptical attitude towards fast breeders, underlining in particular the reliability problems that the thermal reactors had suffered, the "brochure assessments" on which thermal reactor choice had frequently been based, and the high cost of fast breeders.

The documentary material provides frequent references to the scepticism of the CEBG with regard to fast breeders. For example, as early as 1976, Kenward (1976b, 171) explained the support of CEBG to wave power by its capacity to undermine the

development of fast breeders, noting that the CEBG seems to “have an aversion to breeder reactors; it pounces on any development that could make them unnecessary”. However, in the early 1980s, the CEBG still officially considered fast breeders as the logical next step from thermal reactors, provided that the technical feasibility of fuel fabrication and reprocessing could be established.<sup>57</sup> Later, the proposals for energy sector liberalisation in the late 1980s provoked profound unintended effects within the CEBG, notably by diminishing its interest towards nuclear power in general. Winskel (2002, 457) evokes John Baker as a personification of this reversal: as CEBG Managing Director, Baker argued that nuclear had ‘by far the cheapest generating cost’, while just four years later, as Chief Executive of National Power, he portrayed nuclear as ‘a restriction on the CEBG’s ability to compete’. Whilst the nuclear physicist Lord Marshall continued to display a reverential commitment to nuclear technology, Baker, a former civil servant, quickly abandoned his allegiance.” (Winskel 2002, 457)

Illustrative of the widening gap between the AEA’s and CEBG’s operating logic during the process of electricity sector privatisation was the change in the personal opinion by Walter Marshall. Conway (1989, 64) hence notes that despite having advocated fast breeders as the “sensible next step in nuclear power” during his time at the AEA, “since becoming a captain of incipiently private industry he has more or less told the government to fund the work itself, and the government’s response has been virtually to drop the project”.

## 6.5 Policy and Politics

### 6.5.1 British industrial policy – or the absence of it?

The absence of a concerted effort and strategy to build national champions and develop national industries has been a defining feature of British policy in much of the post-War era, and evoked by most interviewees – who often mentioned the coherence of the French industrial policy as an illustrative contrast to what they saw as the British absence of nuclear and industrial policy. As underlined by Rush et al. (1977, 97-98), the government policy in the 1950s and 1960s, which led to the multiplication of consortia building nuclear power, and the avoidance of consolidation of the industry, did not seem to achieve its objective of greater competition. What is more, it tended to spread resources too thinly, as none of the consortia alone had the sufficient design engineering capacity required to make successful reactors on a commercial scale (ibid.). The economic crisis following the first oil crisis accelerated the decline of the British manufacturing industry, and probably did not help the nuclear industry either. Furthermore, some interviewees, notably those speaking in favour of fast breeder technology, considered this “lack of coherence” as a major shortcoming and a reason for the decline of fast breeders, while others questioned

<sup>57</sup> Britain joins European breeder club. *New Scientist*, 8 September 1983, p. 669. [http://books.google.co.uk/books?id=aBUDS\\_G-SU8C&pg=PA669&lpg=PA669&dq=CEGB+fast+breeder&source=bl&ots=QkzVV069IL&sig=FqgC69uLAAv7zCLNghV3TCFBOHI&hl=en&ei=E3OxTbzQPIau8QOHrWWDA&sa=X&oi=book\\_result&ct=result&resnum=1&ved=0CB0Q6AEwAA#v=onepage&q=CEGB%20fast%20breeder&f=false](http://books.google.co.uk/books?id=aBUDS_G-SU8C&pg=PA669&lpg=PA669&dq=CEGB+fast+breeder&source=bl&ots=QkzVV069IL&sig=FqgC69uLAAv7zCLNghV3TCFBOHI&hl=en&ei=E3OxTbzQPIau8QOHrWWDA&sa=X&oi=book_result&ct=result&resnum=1&ved=0CB0Q6AEwAA#v=onepage&q=CEGB%20fast%20breeder&f=false).

whether such a policy was needed. According to this latter line of argument there was no reason why the UK could not operate nuclear plants without necessarily having its own nuclear technology, let alone fast breeder technology. Some of our interviewees put the argument somewhat provocatively claiming that that the UK history of fast breeders was perhaps actually a prime example of good industrial policy: one should not invest in a technology that recurrently fails to deliver on its economic promise.

The argument put forward by the AEA informants was obviously different: the problem with British industrial policy was its lack of orientation, coherence and long-term character – the “inability to stick to a policy for longer than a couple of years”. Since these interviewees had not given up their perception of fast breeders as the ultimate objective of a ‘rational’ policy on nuclear energy, and given the long period of R&D required to bring fast breeders into being, they argued that the government should take the responsibility for continued funding for fast breeder R&D. The arguments of climate change and ‘sustainable use of the resource’ were further brought forward to support the commitment to the development of fast breeders.

Yet ‘industrial nationalism’ had not completely disappeared from the British nuclear politics even by the 1970s. This type of nationalism was presumably strongest within the Labour party in the early 1970s. Not only did Labour support the construction of AGRs, but when Labour again took power in the early 70s, the party continued to support the SGWHR technology. However, even the Energy Secretary Tony Benn, described by one of our interviewees as a true ‘industrial nationalist’ conceded that the SWGHR would not be an economically viable technology.

### 6.5.2 Declining political support

While our evidence on the subject is patchy, it seems that the political support for fast breeders in the UK followed a trajectory similar to the one observed in France, with the 1970s as the crucial decade in which the decline and doubt decisively set in. A number of factors contributed to the declining political support. Many of the above-mentioned external factors were common to both France and the UK, such as the oil crisis and the subsequent rise in the priority given to the construction of thermal reactors, stagnating electricity demand, declining uranium prices and the gradually rising public concern about nuclear safety and proliferation risks. However, in contrast with France, the nuclear industry in the UK had a rather dismal record in developing its thermal reactor programme. Perhaps even more crucially, the prototype reactor in Dounreay had suffered from continuous technical difficulties – again in contrast with the relative success of its counterpart, Phénix, in France. Furthermore, the intense battles – and political log-rolling – around the choice of the thermal reactor type in the 1970s further eroded the legitimacy of the nuclear establishment. According to Patterson (2010, 84), the political support for a commercial fast breeder reactor was withering away in the mid-1970s, and therefore the apparent “closing of



ranks within the UK nuclear establishment” in favour of the construction of commercial FBRs.<sup>58</sup> was not sufficient to ensure the advancement of the programme.

The significance of the entry in power of the Thatcher government was recognised by all interviewees. In particular, the shift in government accelerated the decline in the political power of the AEA. Fast breeders were no longer useful as a tool in Thatcher’s attempts to bring down the political power of the miners’ unions, even though, at the beginning of its mandate, the Thatcher government seems to have given a serious thought to the possibility of continuing R&D on fast breeders. Moreover, Thatcher earned the respect of at least some of the nuclear scientists and engineers, and was described by one of our AEA informants as “extremely intelligent and scientifically literate – by far the most scientifically intelligent of our prime ministers”. However, while Thatcher had – according to one of our interviewees – “huge trust in nuclear”, the government took great care to keep the options open and a keen eye on the economic performance and value for money. This was also the approach that Thatcher adopted towards the AEA – paramount for decisions concerning the AEA was whether the organisation was going to deliver on its mission and provide good value for money.

The electricity market liberalisation and privatisation introduced by the Thatcher government has frequently been described as the origin of the long period of decline of the UK nuclear industry since the mid-1980s, and the same explanation was used by many of our interviewees to explain the demise of the fast breeder programme. While the closer economic scrutiny introduced by Thatcher undoubtedly contributed to the end of the fast breeder “dream”, the evidence seems to indicate that the privatisation alone could not explain the decline. Rather, the underlying philosophy underpinning privatisation – in particular the strong emphasis on economic performance – to a large extent existed already prior to the actual act of privatisation, and had substantially weakened the fast breeder programme.

### 6.5.3 Privatisation, liberalisation and the ‘economic dogmatism’

Arguably, the lack of short and medium-term economic profitability – further compromised by the high investments in R&D to develop the technology – were among the main factors that brought an end to fast breeder development in most countries, including Britain. The fundamental change in the criteria for economic assessment of nuclear energy brought about by the energy sector liberalisation plans in the 1980s was probably the single most important factor that contributed to the decline of FBRs’ attractiveness. Fast breeders were called into question on cost grounds also by industry insiders. For instance, the magazine *Nuclear Engineering International*, in 1983, called into question “the vast sums that have been spent and the much greater sums that will need to be spent before the fast reactor can become a commercial option for electricity utilities” (Patterson 2010, 86)

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<sup>58</sup> In 1977, the Select committee on science and technology recommended that a commercial fast breeder reactor be built, and John Hill – the chairman of the AEA at the time – concurred (Patterson 2010, 84).



The discussion on the economics of fast breeders brings us back to the question of ‘external’ versus ‘internal’ factors in affecting the development of a technology. For the fast breeder advocates, economics was clearly an ‘external’ factor that could only hamper and distort research towards fast breeders. The alleged short-sightedness introduced by the emphasis on economic efficiency and project-based management could only harm the objective of long-term development of a nuclear technology, which would represent ‘sustainable use of the resource’ (uranium). For the critics and ‘economically-minded agnostics’ (the majority among our interviewees), the introduction of economic performance criteria was necessary in order to bring the nuclear scientists and engineers ‘down to earth’, and prevent undue costs to society from scientific ‘fantasising’. To the extent that they are based on the premise of autonomous ‘technological’ or ‘economic’ analysis, both of these perspectives are flawed. While the FBR advocates tended to assume that a technology can be judged on its technical performance and potential alone, those arguing in the spirit of ‘pure’ free market economics make a similar assumption about the existence of independent and unquestionable economic fundamentals. By contrast, experience has over and over again demonstrated the dependence of the outcomes of economic analysis on the underlying assumptions (e.g. Hodgson 1989), as well as the inseparability of technological performance from the broader economic, institutional and political context in which a given technology is being developed (e.g. Latour 1992).

While decision-making on fast breeders – and on nuclear power more generally – became more open to perusal by participants outside the ‘inner circle’ of nuclear experts, this happened primarily through the introduction of greater economic scrutiny. It could be argued that the relative abundance of argumentation in the UK around the costs of nuclear energy and fast breeders in the 1980s was partly a reflection of Thatcher government’s efforts to introduce economic liberalism. Many academic scholars and independent experts then seized the opportunity of contesting government’s own policy, precisely in order to check the government’s adherence to its principles of economic efficiency. As economics became the central instrument used by the various parties in energy policy debate, the supporters of fast breeders found it increasingly difficult to defend their arguments, which tended to reason “as if economics did not matter”. A typical example of the way in which economic logic was employed in order to uncover the allegedly faulty rhetoric of fast breeder proponents is provided by Sweet (1982, 19-20), in his refutation of Walter Marshall’s “energy value” argument:

*“Walter Marshall's... concept that the UK 'needs' the programme because it needs the energy from uranium... is an appeal that lies outside the efficient use of national resources, as understood by economists. Exploitation of uranium in the earth's crust is not in itself a justification for nuclear power, no more for example than it is a reason per se that we should mine sea bed minerals just because they are there... I therefore disagree in principle with Marshall's statement that 'In an energy hungry world the idea of burying spent fuel and not making use of it is grotesque'. I should certainly regard it... even more grotesque to divert scarce resources from those areas of the world that presently suffer severe deprivation, in order to build fast reactors.*

Sweet further denounces what he considers an excessively value-laden approach adopted by Marshall, which according to Sweet (1982, 19-20) “*may be ideologically appealing to some but is not a satisfactory way to argue the case for a particular technology.*” By contrast, “[t]he acceptance of a principle of economic evaluation is central to public decision making, and it is a matter of the greatest importance whether the fast reactor debate will take place within the context of an economic method, applied with some rigour, or whether the obfuscation that the energy value argument has cast over the last public inquiry at Windscale might be present at the next.”

## 6.6 NGOs and public opinion

We have only limited evidence on the role of public and NGO opposition against fast breeders and nuclear power. Most of our interviewees considered public opposition as having had only minor importance, yet this finding possibly reflects two biases in our research setting. Firstly, only two of the interviewees had participated in nuclear policy and debate as active representatives of civil society. Secondly, and perhaps more importantly, the interviewees probably interpreted the term ‘influence’ more narrowly than we had wished – as direct and concrete impact on policy decisions concerning the fast breeder programme. Hence, Patterson provides plenty of evidence to demonstrate that the mounting public concern over the health effects of Dounreay – but also, and above all, of nuclear energy in general – precipitated the decline of the fast breeder programme. Indeed, social movements certainly did not contribute much to the concrete decisions on fast breeders, and no direct causal link can be established between the action by those movements on the one hand, and the decisions on the other. If there was an impact from social mobilisation, it certainly was more indirect and subtle. For example the discovery of a radioactive particle of spent fuel on beaches adjacent to Dounreay in 1983 and the Chernobyl accident were, according to this view, decisive in the decision to abandon R&D into fast breeders.

However, the observation about the weak impact of citizen opposition on decisions over fast breeders in the UK is in line with findings from earlier research, which have concluded that the anti-nuclear NGOs and citizen movements in the UK were weak in the 1970s and 1980s (e.g. Kitschelt 1986; Koopmans and Duyvendak 1995, 246; Twena 2006). Hence, Chafer (1985) notes that the core of the anti-nuclear movement in the UK in the 1970s and 1980s was within the peace movement – targeting the military use of nuclear – while in France there was a strong opposition against nuclear power until the end of the 1970s. Rucht (1995, 287), in turn, places Britain within the same group with the Nordic countries and Italy as countries with very weak citizen resistance between the mid-70s and late 1980s against nuclear power (with weaker anti-nuclear movements only in Canada and Belgium). Finally, Rüdig (1990, 352) draws attention to one specificity of the British anti-nuclear movement, that is, its seeming inability to take advantage of the considerable difficulties that the UK nuclear sector had encountered throughout its history:

*“Throughout the history of nuclear power in Britain, many delays were not due to anti-nuclear opposition but due to problems located within the industry. The British*

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*anti-nuclear movement found itself largely unable to exploit the difficulties in the nuclear sector.”*

As co-founder of the UK Friends of the Earth and arguably one of the most prominent experts of the history of UK nuclear politics, Patterson considers the Flowers report as a major milestone, while nevertheless not seeing it as the primary reason for the abandonment of fast breeders. Allegedly Flowers was the first since a long time to suggest that there were “serious fundamental difficulties” in the fast breeder technology (Patterson 2010, 83). A major factor concerning the influence of the Flowers report was its timing, at the moment when rumours circulated that a commercial fast breeder reactor would finally be constructed (Patterson 2010, 82). According to Patterson (2010, 84), “[a]fter the publication of the Flowers report, on 22 September 1976, the prospect for even a single large fast breeder in Britain became distinctly bleaker”. This can be interpreted as a manifestation of the elemental role that one of our interviews attributed to NGO action in destabilising and weakening the ‘nuclear regime’ internationally, as it consistently drew public attention especially to problems of nuclear safety and proliferation. This eroded the trust and political capital that the fast breeder reactor community would have needed to make fast breeders a reality. Such international influence was also evoked in a news article published in *Europe Energy* (1992), after the UK government’s decision to withdraw from the European fast breeder cooperation: “This comes five months after the French Government, under pressure from ecological groups, had to suspend starting up the French Superphénix fast-breeder reactor.”

Most of the interviewees, however, judged the role of public opposition in a way similar to that of the Flowers report: neither had much impact on decisions, but they possibly helped shape the general atmosphere. The report by Pearson (1979) from an energy and fast breeder conference in 1979 provides an example of such changes in ‘atmosphere’: apparently public participation was recognised as a major need by the conference participants, yet a topic that had hitherto attracted too little attention by policymakers and researchers. Most interviewees agreed that the Flowers report was potentially powerful precisely because its chairman came from the inside of the ‘nuclear establishment’. Some conceded to the suggestion that the report had nevertheless produced an effect by somewhat changing the tone of the debate and for the first time seriously calling into question the reasonableness of developing fast breeder technology. One interviewee noted that while the Flowers report “led to a lot of good things”, for example helped to foster increased citizen engagement in planning and decision-making, it did not really influence the FBR project.

A further possible reason why NGO action may have had an impact, but only indirectly, was evoked by one of our interviewees. The anti-nuclear NGOs in the UK gave a clear priority in their campaigning to the opposition against reprocessing. Their judgement was that ‘attacking’ fast breeders would not be the best use of resources, since reprocessing was seen as the crucial and vulnerable link in the entire logic underpinning the ‘all nuclear’ vision. This prioritisation was presumably further reinforced by the belief, expressed by many of our interviewees, that there were inherent technological weaknesses that would inevitably lead to the demise of FBRs.

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## VII. CONCLUSIONS: WHAT AND WHO KILLED THE FAST BREEDER REACTORS IN BRITAIN?

In this concluding section, we shall examine, one by one, the various explanations given by our interviewees and expressed in the documentary material concerning notably the reasons for the abandonment of the UK fast breeder programme. The presentation does not seek to ‘reveal the truth’, or provide the ‘correct’ answer to the question of why the fast breeders were abandoned. By contrast, the aim is merely to briefly summarise and analyse the logic behind the different arguments.

### 7.1 Economics and technology: autonomy or dependence?

Probably the most frequently expressed argument was that the fast breeders were economically unviable from the very beginning and that their poor economic performance was ‘revealed’ once the programme was subjected to greater economic and financial scrutiny. Another variant of the economic argument was that the fast breeders might have been economically unprofitable in the short run, but that their medium- and long-term potential was destroyed by the excessive emphasis on economics introduced progressively from the mid-70s onwards. The decline in uranium prices was mentioned by almost all of our interviewees as a major component undermining the logic behind FBRs. According to the proponents of fast breeders, the technology as such is tried and proven in theory and at small scale, yet they considered the major mistake of UK nuclear policy to have been the application of strictly commercial evaluation criteria to the assessment of a technology that had not yet reached a deployment stage. Since the fast breeder advocates deemed the technology as indispensable in solving the world’s energy problems in the future, they criticised such economics-dominated thinking about leading to short-termism and working against the long-term sustainability objectives.

A frequent counterpart and parallel to the economic argument was the claim that the technology was either ‘objectively’ proven or ‘inherently’ flawed and unviable. The proponents of the former view repeatedly asserted that the technical viability of the technology had been demonstrated, that the technical problems encountered in the application of the technology were related only to the ‘conventional’, non-nuclear, part of the technology, and that R&D into fast breeders should be vigorously pursued in order to prepare for the inevitable future scarcity of energy and uranium resources. The critics of FBRs, in turn, considered that since the technology was simply too complicated to be economically viable within any foreseeable timescale, and given that numerous alternative electricity-generation options were available, it would not make sense to invest in excessively complicated technology, “merely to boil a kettle of water”. From this perspective, there was no mystery: the FBR technology is inherently unviable and it simply killed itself, without any need for ‘external intervention’.

Common to a lot of the argumentation of both the proponents and critics of FBRs was the in our view questionable assumption that the economics and the technical viability of a technology could be assessed independently, in isolation of the broader context within which the technology is being developed. The fundamental shift in the

‘goalposts’ of the evaluation of various energy technologies that was brought about by the preparation for the liberalisation of the UK energy supply industry provided a particularly vivid example of the contingency of economic assessment on the underlying framework and hypotheses. The assumption about the ‘inherent’ (un)viability of the technology is likewise highly deficient: the economic performance, including notably the predictions concerning energy forecasts, and the development of the various alternative technologies, is part and parcel of the process whereby the viability of a technology is constructed.

## 7.2 Hype, disappointments and ‘the reality’

One strand of argument highlighted the apparent contradiction between the extremely optimistic visions from the 50s and 60s concerning the FBRs, and empirical evidence. This gap between the expectations and ‘the reality’ meant that there was simply no way the technology could actually survive. To illustrate the argument, a comparison was made with nuclear fusion: it was far easier for the proponents of fusion energy to entertain the idea this technology would actually provide a solution to the energy problems, because fusion had not yet been tested on any significant scale. This view again highlights the socially constructed nature of the viability of a technology: an essential element in the construction of the viability of a technology consists of the confrontation of the technology with its external environment. However, contrary to the assumption that the FBRs were tested against ‘the reality’ – which turned out to be different from the one assumed in the optimistic predictions of the 1950s and 1960s – it would be more accurate to argue that the fast breeder project failed to adapt itself to its constantly changing environment and institutional context. As many examples from the development of technologies in other sectors have demonstrated (e.g. Konrad 2006; Geels et al. 2007), the explanations for the emergence of over-optimistic forecasts are manifold. On the one hand, especially on technological ‘megaprojects’, which have no precedents against which one could compare their likely viability, forecasting is often in the hands of the ‘insiders’ who have a natural disposition to ‘believe’ in the potential of the technology (e.g. Flyvbjerg 2007). On the other hand, the proponents of a technology also have an interest in exaggerating its future potential, for instance in order to attract research funding and gather political support needed to render the technology viable. In exaggerating the potential, the advocates nevertheless risk compromising the very viability of the technology. By precipitating the inevitable disappointment once the inflated expectations fail to materialise, the advocates hence undermine the forces that are essential for the construction of the viability of the technology. While this type of ‘hype-disappointment’ cycles are a frequent phenomenon in technology development, in the case of FBRs, the strong independence of the fast breeder community – notably the AEA – accentuated the disappointment once the AEA was forced to come out from its isolation.

## 7.3 External events

In view of the considerations put forward above, the argument frequently evoked especially by our AEA informants about the importance of ‘external events’ can be called into question. The proponents of FBRs frequently underlined that the decline of



uranium and oil prices and the alleged ‘excessive alarmism’ generated by ‘incidents’ such as Chernobyl and the Three Mile Island, precipitated the decline of FBRs. ‘Overreaction’ to such ‘incidents’ would have made nuclear energy in general and fast breeders in particular a political hot potato, which the politicians did not dare to touch. Therefore, in the final analysis, it would have been the lack of political courage that led politicians to avoid difficult decisions that would have been in the long-term interest of Britain and the humankind. According to this line of thinking, similar ‘external’ factors included a wide range of issues such as the domination of economic rationality, which the Thatcher government introduced in the sector. Again, this view was underpinned by an assumption about the autonomy of technology: rather than becoming viable through the confrontation and ‘negotiation’ with its environment, a technology would be independent from its social context, and constantly threatened by external forces devoid of sufficient understanding of the nature of the technology. Such an approach also entails a particular view of the nature of expertise: the only truly valid form of expertise in the area of nuclear technology would be that of nuclear scientists and engineers, while economists and politicians would be devoid of a proper understanding of the ‘true’ nature of the technology and could therefore only ‘interfere’ in the process, with unavoidably harmful impact as the main result.

#### 7.4 Social & safety concerns

Another ‘external’ factor that the many FBR advocates perceived as an obstacle to the presumably harmonious development of the technology was public opposition against nuclear energy in general and fast breeders in particular. However, most of our interviewees considered that public opposition and citizen movements had been of limited significance; protests never caused any significant changes in the actual decisions on fast breeders. One interviewee, with first-hand experience from anti-nuclear movement, in turn, strongly emphasised the significance of public opposition, as elemental in eroding support for nuclear power in general, and destabilising the international ‘nuclear regime’. The civil society targeted its opposition against the “plutonium complex” – reprocessing, FBRs and MOX (mixed oxide fuel) – and refused to make a distinction between the military and civilian applications of nuclear technology.

An alternative interpretation would see public opinion as an essential part of the context in which a technology is to be applied. Far from being external to the technology, the public opinion would be at the same time shaped by the development of the technology and one of the factors shaping its viability. An obvious example was the way in which the civil society exerted its impact on FBR economics: the numerous ‘incidents’ and accidents raised safety concerns among the public, led to citizen protests, and thereby increased the pressure on the authorities to tighten safety regulation which in turn increased the costs and reduced the economic attractiveness of nuclear energy and FBRs. As expressed by one of our interviewees, as “the world” became more concerned about safety issues, the FBRs gradually went out of fashion even among the pro-nuclear groups. Especially in the US, the price of nuclear energy increased progressively throughout the 1970s, and the Three Mile Island accident in 1979 triggered very significant changes in safety regulation.



## 7.5 Political power play and declining political support

Somewhat surprisingly, the arguments put forward to explain the fall of the FBR project seldom made reference to strategic and tactical power play and ‘politicking’. By contrast, the dominant explanatory narratives emphasised, respectively, the inherent economic and financial unviability of the technology or its equally inherent viability, and the unrealistic expectations entertained by the nuclear scientists or the excessively short-term thinking by the policymakers. The most often evoked political/strategic motivations referred to what was described as the overwhelming political objective of Margaret Thatcher – crushing the power of the coal miners’ unions. According to this argument, Thatcher put aside her otherwise favourable view of nuclear technologies in general, once it became clear to her that the fast breeder technology would not help her to achieve her political objectives. Another example of strategic reasoning was the reference to the battle within the AEA between the proponents of nuclear fusion and fast breeder technologies. Hence, the demise of the fast breeders would have been partly a result of the victory of the proponents of fusion reactors in the battle for resources.

Political power play was, however, clearly present in the process of FBR development in particular in the continuous decline of the influence of the AEA and the concomitant rise in the power of the CEGB in decisions concerning nuclear energy. These shifts provide a further illustration of the inseparability of economics, politics and technology. Firstly, the political objectives and ideological conviction of Margaret Thatcher were decisive in changing the criteria used for assessing energy policy options. Thatcher’s liberalisation agenda introduced a particular perspective to economic appraisal and greatly strengthened the weight of economics in political argumentation in general. Rather than an interference of economics in the sphere of technology, the ‘Thatcherite revolution’ was a manifestation of one specific way of constructing the economic argument. Secondly, the change of the ‘goalposts’ of appraisal had been in gestation all the way through the 1970s, and contributed to the decline of the political clout of the AEA. As underlined by Winskel (2002), it would be unhelpful to perceive the loss of power of the AEA as an external intrusion into the operation of an autonomous, ‘purely technological’ institution. Instead, this loss of power could be perceived as a result of the changing environment, entailing a shift in power relations between technology developers and engineers on the one hand, and the retailing and commercial side on the other hand. The AEA’s attempts to ‘black-box’ (Winskel 2002, 456) the nuclear programme in order to retain its institutional status and influence can be seen as a key reason for the demise of the FBR programme: by isolating the technology from its institutional environment, the AEA in fact prevented the necessary process of adapting the technology to its context.

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